RE-ORDER NO. 65-757

FINAL REPORT

"PRELIMINARY DESIGN OF A GEOLOGIC SAMPLE ACQUISITION AND TRANSPORT DEVICE"

OCTOBER, 1965

FOR

JET PROPULSION LABORATORY OF
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

CONTRACT NUMBER 951178

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BY

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PREFACE

This preliminary design work was performed by Research Department personnel of the Hughes Tool Company, Oil Tool Division, Houston, Texas, under Contract No. 951178 from the Jet Propulsion Laboratory, Pasadena, California, and covered the period May to October, 1965.

This work was done under the general direction of T. N. Williamson, Director of Industrial Research, and with the full support of Dr. D. J. Martin, Vice-President of Research, and M. E. Montrose, President of the Oil Tool Division. R. O. Bredthauer served as Project Manager, and W. T. Jones as Project Engineer. The manuscript was authored by W. T. Jones and R. O. Bredthauer. Other Hughes Tool Co. Research and Engineering Department personnel rendering valuable service were V. W. Parish, M. R. English, D. L. Imler, A. D. Wilkinson, K. W. Coffman, A. E. Dykes, and R. M. Strickland.

Foster-Miller Associates, Inc., of Waltham, Massachusetts, under the direction of Dr. Eugene Foster and Marvin Menzin, were engaged during the concept generation phase to seek independent solutions to the design problem. Their assistance is gratefully acknowledged.

We are indebted to Mr. Jack Brown of the Welex Division of Halliburton Company for assistance in evaluation of the explosive coring concept.

In response to a specific provision of this contract, a proposal has been submitted to Jet Propulsion Laboratory for the development, manufacture, and testing of the preferred design of the Geological Sample Acquisition and Transport Device described in this report.

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SUMMARY

A concept design for a breadboard model of a Geologic Sample Acquisition and Transport Device is described. This device will take a three cubic centimeter sample of rock from under a twelve inch layer of overburden and transport the sample, uncontaminated by the overburden, to a point above the overburden surface and deposit it in a tray for subsequent analysis. The overburden may also be similarly sampled. The device is designed to acquire overburden and rock samples through ports to the interior of the rotary-impact bit, to seal the bit interior by rotary valving, and to transport the batch sample to the surface by means of a gas system. An outer barrel provides a means of excluding overburden during rock sample acquisition. The approach taken in the generation of concepts and development of the design is described, and the original concepts along with investigations and evaluations are included in an appendix. Author

Section 1

INTRODUCTION

1.1 PURPOSE

The purpose of this study is to prepare a conceptual design of a breadboard Laboratory model of a Geological Sample Acquisition and Transport Device (GSATD) which can acquire a sample of unknown rock and transport it to an X-ray diffractometer or other instrument for analysis. This device is to perform satisfactorily under earth gravimetric and atmospheric conditions. Since the ultimate flight model which may develop from this breadboard may be used on the later Surveyor flights or in the Voyager program, the goals of a flight model must be kept in mind. The mechanism must be as simple as possible in order to increase reliability, overall weight and power requirements should be kept as low as practical for a breadboard model, and components should be capable of ultimately operating in hard-vacuum conditions with large temperature variations.

1.2 PERFORMANCE REQUIREMENTS

The GSATD is to acquire three (3) cubic centimeters or more of uncontaminated, unaltered, and unsorted fragmented rock or other subsurface material encountered. That is, the sample is to be representative of the location from which it is acquired. Fragmented rock shall be acquired from solid rock which is covered by a cohesive or noncohesive overburden at a depth of approximately one foot. This sample shall then be transported to a short distance above the overburden surface. Further sample preparation and transfer to the analyzing device is not a part of the required concept. The device also shall have the capability of acquiring a sample of highly vesicular, rather than solid, rock which is covered by a similar overburden; this sample also is to be transported to a short distance above the overburden surface. In addition, the layer of overburden is to be sampled; samples shall be obtained from a bed of the following types of particulate material and transported to a short distance above the surface:

1. Cohesive powder - 37 microns (μ)
2. Noncohesive particulate - sand of 1 - 2 millimeters (mm) size
3. Rubble - micron size to several mm

The main goals to be achieved by the breadboard device are:

1. The acquisition of a rock sample from under and the transportation to a point above unconsolidated overburden material without contamination of the rock sample by the overburden.
2. The acquisition of high porosity, low density consolidated or unconsolidated overburden material.

Emphasis is to be on acquisition and transportation of the sample rather than on fragmentation or drilling of the rock. However, if the fragmentation process is integral with the acquisition and transport process, it shall be considered. If the device employs a drill for the fragmentation process and the sample is acquired through a drill bit, a commercial drill motor may be used to demonstrate the drilling-acquiring mode.

The following overburden and rock combinations were suggested for eventual testing of the breadboard device:

1. Basalt rubble
2. Basalt

3. Pumice

4. Basalt under 25 centimeters (cm) of quartz dust (37μ)

5. Basalt under 25 cm of quartz sand (1-2 mm)

6. Basalt under 25 cm of quartz rubble (dust, sand, pebbles)

7. Pumice under 25 cm of basalt dust

8. Pumice under 25 cm of basalt sand

9. Pumice under 25 cm of basalt rubble

10. Basalt dust at surface

11. Basalt sand at surface

1.3 APPROACH TO CONCEPT DEVELOPMENT

The overall problem first was divided into three sub-categories, as follows:

1. Overburden removal or exclusion and sampling of the overburden.
2. Sampling of the rock
3. Transport of the sample

Concept-generation sessions were held on each of the above sub-categories. With the exception of the Project Manager and the Project Engineer, who attended all sessions, different engineers with various backgrounds participated in each of the meetings. Ideas were not necessarily limited to the specific session subject; some discussion of the overall problem occurred in each session.

Upon completion of the three sessions a concept documentation system was established. Each concept, or partial concept, was sketched and described, advantages and disadvantages were listed, and concept numbers were assigned. The resulting twenty-three concepts were arranged into eight groups with the concepts in each group being variations of the same basic idea. Each group was then investigated in detail and the feasibility of the basic idea determined.

Concurrently, Foster-Miller Associates, Inc., a consulting engineering firm of Waltham, Massachusetts, was engaged to conduct an independent investigation. Their task was to generate concepts of their own, evaluate them, and recommend a preferred system to the contractor.

At the preliminary design presentation, the results of the investigations of the eight concept groups, were presented to JPL, along with the concepts generated by Foster-Miller. A numerical evaluation procedure was developed to determine the concept which had the best possibility of meeting all requirements. This evaluation is shown in Appendix C. On the basis of this evaluation and work already in progress at JPL, it was decided to concentrate further effort on one of the Hughes Tool Company (HTC) groups and on one of the concepts submitted by Foster-Miller. These were developed further and presented at the final design review. As a result of this review, a design based on HTC Group 1 (Gas Transport through a Double Wall Tube) was determined to be the best approach, and this is presented in this report as the preferred design.

1.4 ORGANIZATION OF REPORT

The preferred design is described in detail in Section 2 of this report. Some alternate designs which were developed past the initial concept stage are described in Section 3. Development of these concepts was halted when their limitations became obvious.

The initial concepts are documented in the appendices. Appendix A consists of Foster-Miller progress reports which describe and evaluate their concepts. The reports of investigation of the HTC concepts are in Appendix B, and the numerical evaluation of all concepts presented at the preliminary design review is shown in Appendix C.

Section 2

PREFERRED DESIGN

2.1 DESCRIPTION

The preferred concept design is shown in Figure 1. The arrangement of the various components of the GSATD mechanism is shown in Figure 1 along with the supporting structure; the details of these components are shown in Figures 2 and 3 and described in the following sections.

2.1.1 Supporting Structure

The main supporting structure is made up of the Base, Supports, Model Base, Support Tube, Lead Screw, and Top Plate. On this stationary structure is mounted a movable structure, Plates 1 through 6, Gussets 1 through 3, and the Lower Framework, which supports the actual GSATD mechanism. The Percussor Housing, besides enclosing the percussion mechanism, serves as a structural member between Plates 1 and 2 and as a support on which the Motor Clamp is mounted. The Nut assembly contains a Nut rotatably mounted in ball bearings, and which engages the Lead Screw and supports the entire movable structure. The details of the Nut Assembly are shown in JPL Drawing No. 6-9376306.

2.1.2 Bit

The Bit is shown at the lower end of the Drill Stem in Figure 2; an enlarged detail view is shown in Figure 3. The cutting element is a tungsten Carbide Blade with a Cuttings Relief Groove. The Carbide Blade is brazed to the Bit Body which is attached to the Drill Stem by a threaded connection. Two Ports are provided, one on each side of the Carbide Blade. Cuttings or overburden pass through these Ports to the interior of the Bit when the

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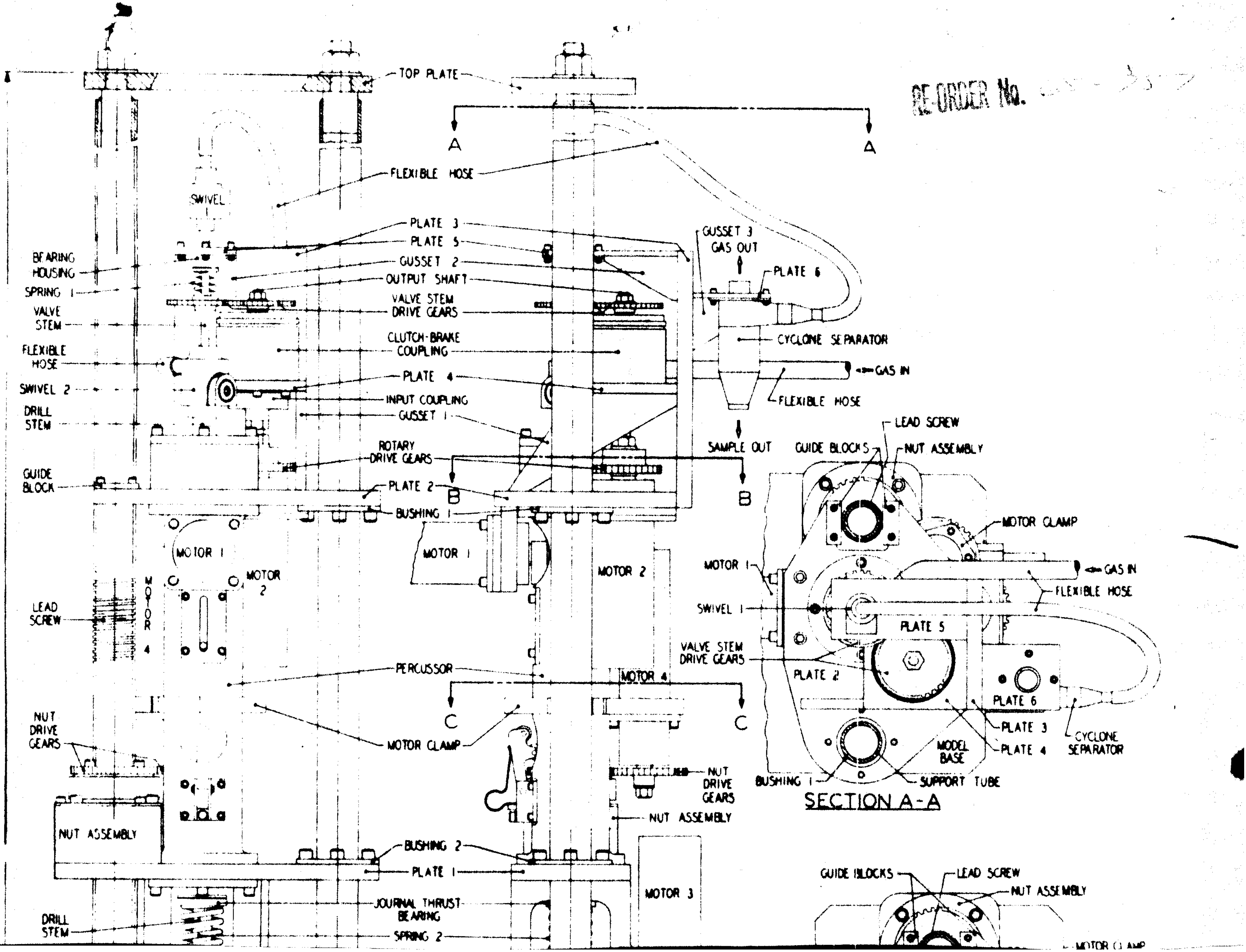
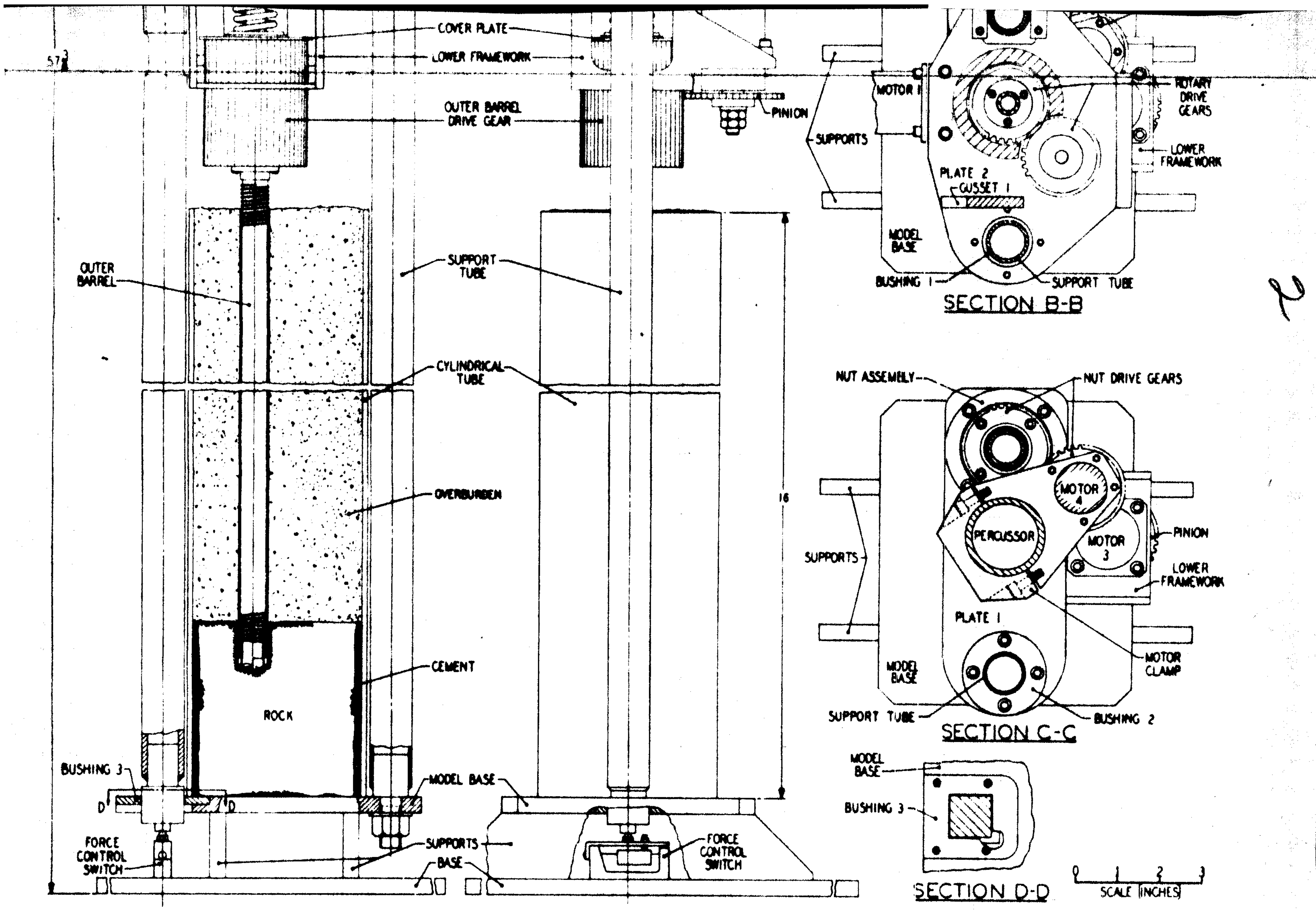


TOP PLATE
A
A
FLEXIBLE HOSE
SWIVEL 1
PLATE 3
PLATE 5
GUSSET 2
OUTPUT SHAFT
VALVE STEM DRIVE GEARS
CLUTCH-BRAKE COUPLING
PLATE 4
INPUT COUPLING
GUSSET 1
ROTARY DRIVE GEARS
PLATE 2
BUSHING 1
GUSSET 3
GAS OUT
PLATE 6
CYCLONE SEPARATOR
GAS IN
FLEXIBLE HOSE
SAMPLE OUT
B
B
BEARING HOUSING
SPRING 1
VALVE STEM
FLEXIBLE HOSE
SWIVEL 2
DRILL STEM
GUIDE BLOCK
MOTOR 1
MOTOR 2
MOTOR 4
LEAD SCREW
MOTOR 1
MOTOR 2
PERCUSSOR
MOTOR 4
C
C
MOTOR CLAMP
NUT DRIVE GEARS
NUT DRIVE GEARS
NUT ASSEMBLY
NUT ASSEMBLY
BUSHING 2
PLATE 1
MOTOR 3
JOURNAL THRUST BEARING
SPRING 2
DRILL STEM
LEAD SCREW
GUIDE BLOCKS
NUT ASSEMBLY
MOTOR CLAMP
GAS IN
MOTOR 1
FLEXIBLE HOSE
SWIVEL 1
PLATE 5
VALVE STEM DRIVE GEARS
PLATE 2
PLATE 6
PLATE 3
PLATE 4
CYCLONE SEPARATOR
MODEL BASE
BUSHING 1
SUPPORT TUBE
SECTION A-A
GUIDE BLOCKS
LEAD SCREW
NUT ASSEMBLY
MOTOR CLAMP



GSATD BREADBOARD MODEL

FIGURE 1

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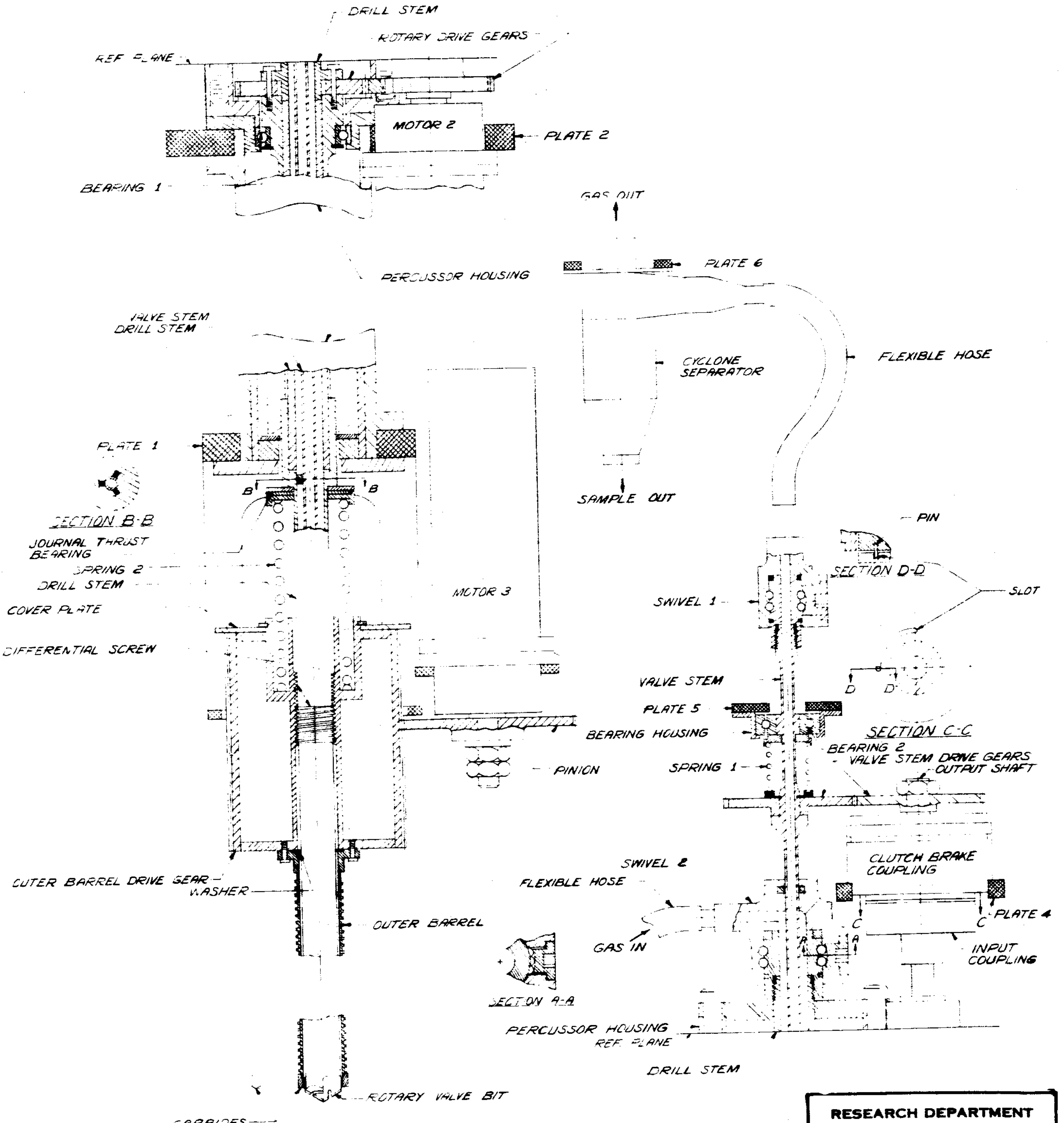

GSATD MECHANISM

FIGURE 2

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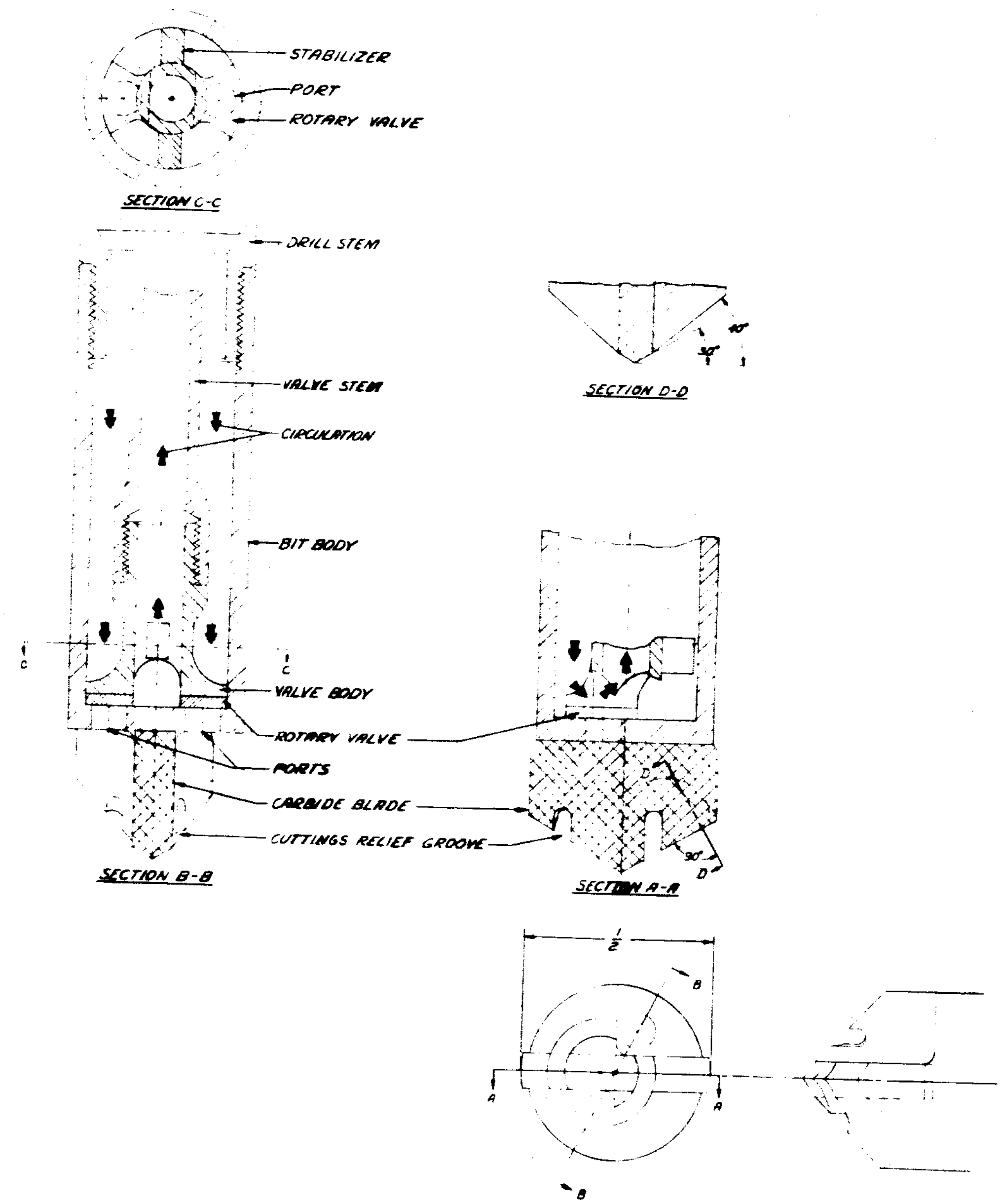

ROTARY VALVE BIT
FIGURE 3

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Rotary Valves are open. Should one of the Ports become clogged, the Cuttings Relief Groove allows free access of cuttings to the other Port thus decreasing the possibility of a reduced penetration rate.

2.1.3 Drill Stem

The Drill Stem is the tubular member to which the Bit is attached. A short distance below the Percussor, male threads are located on the Drill Stem to connect with the Outer Barrel. Inside the Percussor the Drill Stem is made up of several pieces which, in effect, form a tube through the center of the Percussor. At the top of the Percussor the Drill Stem is supported in Bearing 1. Above this, one of the Rotary Drive Gears is attached to the Drill Stem. The other Rotary Drive Gear is attached to Motor 2 mounted outside the Percussor on Plate 2. The motor shown is a permanent magnet, D.C. motor, type BL with attached gear box, made by Globe Industries, Inc. After emerging from the Percussor Housing, the Drill Stem terminates in the rotating member of Swivel 2.

2.1.4 Percussor

The Percussor shown is a modified version of the Percussor shown in JPL Drawing No. 6-9376306. Although the Performance Requirements (Section 1.2) state that they may be used to supply rotary-percussion, commercial drill motors would have to be extensively modified to allow the Drill Stem to pass completely through the motor. Because only slight modification would be necessary to the Percussor already designed by JPL for their Lunar Breadboard Model, it was chosen for the GSATD mechanism. Only the parts shown in JPL Drawing No. 6-9376306 which are directly involved in supplying percussive energy to the Drill Stem are used. Although details of this mechanism are not repeated in Figure 2, the operation is as follows:

Motor 1 (permanent magnet, D.C. motor, Globe type BL with attached gear box) rotates a Crank which is connected by a Connecting Rod to a Hammer Retriever. As the Hammer Retriever rises, it lifts the Hammer which in turn compresses a Spring. At top dead center the Hammer is latched in place with the Spring compressed. As the Crank continues to rotate, the Hammer Retriever is lowered; at bottom dead center the Hammer Retriever releases the Latch, allowing the Spring to force the Hammer down. The Hammer strikes an Anvil attached to the Drill Stem, and the entire process is then repeated. The energy of the blow may be varied by changing the amount of throw in the Crank, by changing the Spring, or by a combination of the two. The number of blows per minute is controlled by the speed of Motor 1, there being one blow for each revolution of the output shaft.

2.1.5 Outer Barrel Assembly

The Outer Barrel is a tubular member which has Carbides brazed onto its lower end, a spiral groove on its outer surface, and a flanged connection on its upper end. This connection assembles the Outer Barrel onto the Outer Barrel Drive Gear. The Washer seats in a recess in the flanged connection and provides a guide for the Drill Stem. The Outer Barrel Drive Gear transmits power from the Pinion and Motor 3 (permanent magnet, D.C. motor, Globe type BL with attached gear box) to the Outer Barrel and also serves as an involute spline, allowing relative vertical movement between the Outer Barrel and the Pinion. The female threads in the Outer Barrel Drive Gear along with the male threads on the Drill Stem comprise the Differential Screw which is used in connecting and disconnecting the Outer Barrel with the Drill Stem. A Cover Plate is secured to the top of the Outer Barrel Drive Gear by a retaining ring. Spring 2 surrounds the Drill Stem between a pocket in the Outer Barrel Drive Gear and a Journal Thrust Bearing, which seats on a shoulder on the Drill Stem. This bearing allows rotation the Outer Barrel relative to the Drill Stem without appreciably increasing the torsional load on Spring 2.

2.1.6 Rotary Valve Assembly

The Rotary Valves are shown in Figure 3 in the closed position. The Valves are mounted on the Valve Body which is screwed onto the Valve Stem. With the Bit disconnected from the Drill Stem, the Valve Stem threaded connection is exposed and may be easily made up or disconnected. The Valve Stem extends through the Drill Stem and emerges from the top of Swivel 2 (see Figure 2). The Valve Stem Drive Gear is affixed to a shoulder on the Valve Stem. Spring 1, which applies a constant downward force to the Valve Stem in order to keep the Rotary Valves seated in the Bit, is mounted between the Valve Stem Drive Gear and Bearing 2. The Valve Stem terminates in the rotatable portion of Swivel 1. The Valve Stem Drive Pinion is mounted on the Output Shaft of the Clutch-Brake Coupling, which is a modified version of the Model PCBF made by Guidance Controls Corporation. A size 20 Clutch-Brake is shown in Figure 2. When this Coupling is de-energized, the Input Coupling is coupled to the Output Shaft; when energized, the Input Coupling is free and the Output Shaft is braked to the housing. The Input Coupling connects the Clutch-Brake Coupling and the output shaft of Motor 2. With the Clutch-Brake Coupling de-energized, the Valve Stem and Drill Stem are both connected to the output of Motor 2 and their relative position remains the same as they are rotated. When the Clutch-Brake Coupling is energized, the Output Shaft is braked thereby holding the Valve Stem stationary while the Drill Stem continues to rotate. The modification to the off-the-shelf Clutch-

Brake, shown in Section C-C of Figure 2, is necessary to limit the rotation of the Drill Stem relative to the Valve Stem to 90 degrees. After a relative rotation of 90 degrees, the Pin and the Slot cause the brake to slip, and the Valve Stem and Drill Stem again remain stationary relative to each other. The Clutch-Brake Coupling may then be de-energized.

2.1.7 Gas Circulation System

For the breadboard model, gas may be supplied from a commercially available pressurized cylinder commonly used in inert gas shielded welding operations. A flow control valve mounted on the cylinder is used to set the desired gas flow; a Solenoid Valve is used to remotely turn the gas flow on or off. These components are not shown in Figure 1; all other parts of the circulation system are shown. From the Solenoid Valve the gas goes through a Flexible Hose to Swivel 2. The Swivel 2 shown in Figure 2 is a concept based on the general design of a ball bearing swivel made by the Chicksan Company. The Deublin Company in Northbrook, Illinois makes such a swivel with two gas passages, but further investigation will be necessary to determine whether the correct size swivel is available off the shelf. From Swivel 2 the gas flows down the annulus between the Drill Stem and the Valve Stem. Its path through the Bit Body, where the sample is picked up, is indicated in Figure 3. The gas and sample come up through the Valve Stem, Swivel 1, and another Flexible Hose to the Cyclone Separator, where the sample is separated from the gas. The sample falls from the Cyclone Separator into a sample tray which is not shown. Swivel 1 as shown is a concept based on the larger swivels manufactured by Chicksan.

2.1.8 Controls

A schematic diagram showing the wiring and components necessary for remote

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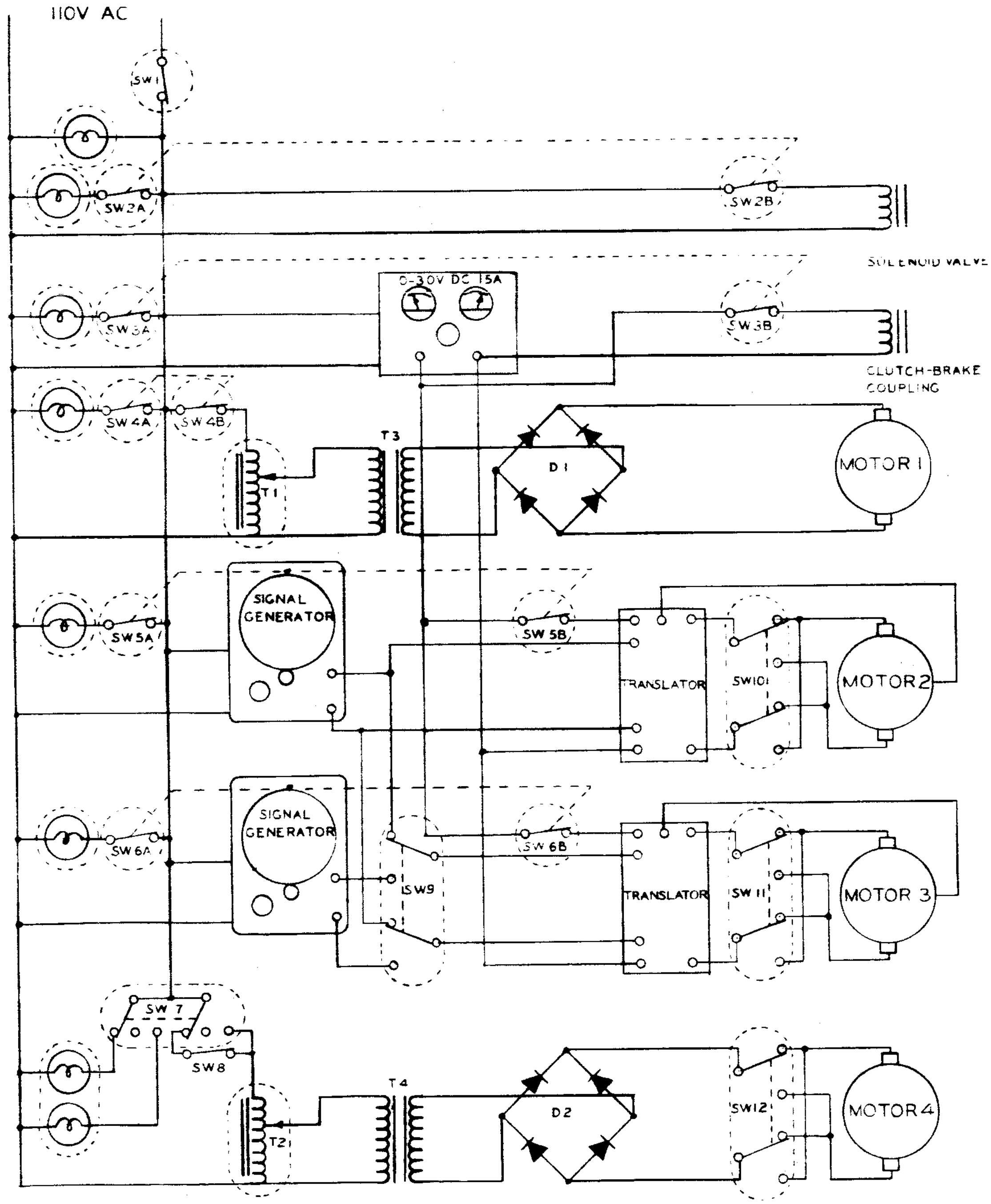
operation of the GSATD is shown in Figure 4. The primary power supply is 110 volt A.C. Switch 1, with its pilot light, is the master on-off switch. Switches 2 through 6 provide on-off capabilities for the various circuits; when the "B" portion activates a particular circuit, the "A" portion activates a pilot light operating on the constant 110 volts of the primary source. The Solenoid Valve is connected directly to the 110V A.C. supply. A Variac (T1), a 110V-24V transformer (T3), and a full wave rectifier (D1) convert the 110V A.C. to variable D. C. power for Motor 1. The circuit for Motor 4 is similar to that of Motor 1 in that a Variac (T2), transformer (T4), and a full wave rectifier (D2) are used. Switch 12 provides the capability of reversing the direction of rotation of Motor 4 while Switch 8 is the Force Control Switch shown mounted on the Base in Figure 1. This switch is manufactured by W. C. Dillon and Company; a flexible beam and a micro-switch provide an on-off force control to operate Motor 4. This switch will have to be calibrated by using a load cell under the Bit before testing begins. In operation it will allow Motor 4 to apply a constant (within one or two pounds) normal load on the Bit. Switch 7 is provided to allow operation of Motor 4 either by Switch 8 or manually; pilot lights are provided both for manual or automatic operation.

A regulated D.C. power supply (0-30V, 15A) operates on the 110V A.C. and provides power for the Clutch-Brake Coupling and Motors 2 and 3. In the operation of the Differential Screw, it is necessary that Motors 2 and 3 be synchronized part of the time and run with a constant speed difference part of the time. A Signal Generator and Translator allow each of these motors to be run synchronously with an A-C signal. The Translator-Motor combination is



CONTROL SCHEMATIC

FIGURE 4

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available from Globe Industries for any of their permanent magnet motors. Switch 9 allows both Motor 2 and Motor 3 to be run synchronously with separate AC signals. Switch 10 and Switch 11 allow the direction of rotation of Motor 2 and Motor 3 respectively to be reversed. All switches, pilot lights, and variable controls will be mounted on a control panel so that all functions of the GSATD Breadboard Model may be controlled from the panel.

2.2 OPERATION

Before a test on a particular overburden-rock model begins, the Force Control Switch should be calibrated with a load cell to give the desired normal force on the bit. The flow control valve on the pressurized gas cylinder should be set to give the desired flow through the gas circulation system. Although the equipment necessary to monitor motor power, rpm, etc. is not shown in Figure 4, these variables should be recorded during a test. The model to be drilled will consist of a rock of the desired type cemented in the bottom of a Cylindrical Tube and covered with overburden of the desired type as shown in Figure 1. If necessary the model can be clamped to the Support Tube for stability.

2.2.1 Drilling Through Overburden

Switch 9 is placed in the position shown in Figure 4 so that Motor 2 and Motor 3 run synchronously with the same signal. Switches 2 and 3 are opened, and Switches 10, 11, and 12 are used to give the desired direction of rotation of the motors. Motors 2, 3, and 4 are then energized feeding the entire mechanism down into the overburden and rotating the Drill Stem and Outer Barrel in the same direction. Since Motor 2 and Motor 3 are synchronized there is no vertical movement of the Drill Stem with respect to the Outer Barrel, and they advance as a single unit. If the overburden is cohesive and percussion is desired, Motor 1 is energized. Percussive energy is applied to the Drill Stem and, through the Differential Screw threads, to the Outer Barrel. Thus in either the rotary or the rotary-percussion drilling mode, the Bit and the Carbides on the Outer Barrel advance as a single unit with the spiral groove on the Outer Barrel O.D. transporting chips away from the drilling face.

2.2.2 Sampling Overburden

When a sample of overburden is desired, Switch 3 is closed, energizing the Clutch-Brake Coupling and stopping the rotation of the Valve Stem. When the Valve Stem begins to rotate again, Switch 3 may be opened and the Valve Stem and Drill Stem will remain stationary with respect to each other. As the Bit continues its advance into the overburden, dust or chips, as the case may be, will be forced through the Ports into the Bit. When sufficient sample has entered the Bit all motors are stopped. Switch 3 is closed, Motors 2 and 3 are reversed and used to close the valves in the Bit. Both motors are used so there will be no vertical movement of the Drill Stem with respect to the Outer Barrel. Switch 2 is used to operate the Solenoid Valve releasing gas which transports the sample from the Bit to the Sample Tray. Switch 2 is opened, the filled Sample Tray is removed, and Switch 2 is again closed allowing gas to flow through the system purging it of any residual overburden sample. Switch 2 is then opened and drilling continues.

If the overburden is under-dense, it will tend to move away from the Bit rather than be forced into the Ports as the Bit advances. In this case

Motors 2 and 3 are connected to their own individual Signal Generator by means of Switch 9. Switches 10 and 11 are set so that when the motors are energized the Bit is retracted inside the Outer Barrel by means of the Differential Screw. When the Bit is retracted far enough, Motors 2 and 3 are again switched to the same Signal Generator and the Drill Stem and Outer Barrel rotated as a unit. Then as Motor 4 advances the mechanism into the under-dense overburden, a slug or core of overburden is contained within the Outer Barrel. The overburden particles are restricted in a radial direction and the possibility of acquisition of a sample by the Bit is enhanced. The Bit may be retracted inside the Outer Barrel until the Drill Stem is completely disconnected from the Outer Barrel. The Cover Plate will not pass through the hole in the lower Framework; therefore, the downward movement of the Outer Barrel with respect to the Drill Stem is constrained. Motor 3 is then reversed from its normal drilling direction of rotation and energized. As Motor 4 advances the mechanism into the overburden, the spiral groove causes the Outer Barrel to act as a screw conveyor, pumping overburden down to the base of the core of overburden inside the Outer Barrel. The "pressure" at the bottom of this core is thus increased thereby increasing the possibility of acquisition of a sample by the Bit. Once the sample is acquired, the Rotary Valves are closed and the sample transported by the gas as previously described.

2.2.3 Drilling Through Rock

If during overburden sampling the Bit has not been retracted inside the Outer Barrel, drilling through the overburden-rock interface will be no different from drilling through the overburden. The Bit and the Outer Barrel will act as a single unit in either the rotary or rotary-percussion drilling mode. If the Bit has been retracted inside the Outer Barrel, Motors 2 and 3 operate the Differential Screw to bring the mechanism back to its original configuration shown in Figure 2. If the Bit has been retracted inside the Outer Barrel enough to disconnect the Outer Barrel from the Drill Stem the procedure is slightly different. The mechanism is advanced to the overburden-rock interface in the disconnected configuration. Further downward pressure supplied by Motor 4 moves the Drill Stem down to engage the threads of the Differential Screw while the downward motion of the Outer Barrel is resisted by the rock. Motors 2 and 3 are then used to rotate the Drill Stem and Outer Barrel so as to achieve the original configuration shown in Figure 2. Motors 2 and 3 are then switched to the same Signal Generator and synchronized; the Bit and Outer Barrel drill into the rock as a single unit.

2.2.4 Sampling Rock

When the Outer Barrel has entered the rock to a shallow depth around its entire circumference, Motor 3 is switched to its own Signal Generator, and the Outer Barrel is rotated in the same direction as, but several rpm slower than, the Drill Stem. This advances the Bit ahead of the Outer Barrel by means of the Differential Screw. When only a few threads are still engaged the entire mechanism may be stopped, raised off bottom, and the last few threads disengaged. This is to prevent shearing or deforming the threads due to the percussion. The Bit is again lowered to Bottom; Spring 2 pushes the Outer Barrel back to its seat in the rock. When Motors 2, 3, and 4 are energized, rotary percussion action and normal load are applied only to the Drill Stem. As the Drill Stem moves down, the Outer Barrel remains stationary and Spring 2 is compressed, thereby holding the Outer Barrel down against the rock. Motor 3 may still be used to rotate the Outer Barrel. The spiral groove on the Outer Barrel O.D. again causes a screw conveyor action, pumping rock chips and overburden particles up away from the Bit.

The Bit is now effectively drilling the rock through an outer casing seated in the rock with a screw conveyor pumping any stray overburden particles away from the bottom of the casing. The Rotary Valves are then opened, the rock sample acquired, the Rotary Valves closed, and the rock sample transported to the Sample Tray by the gas as described above in Section 2.2.2.

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Section 3

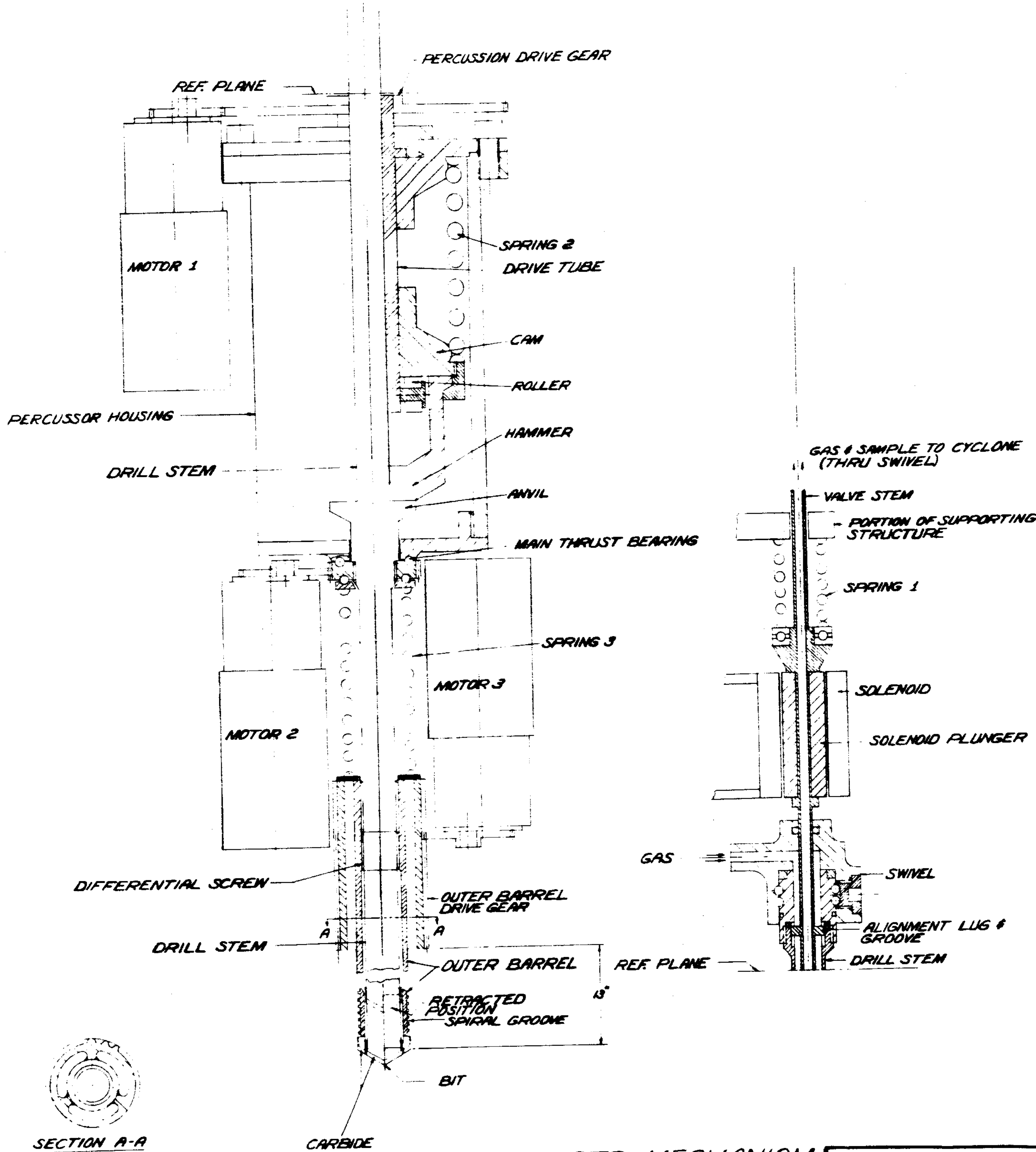
ALTERNATE CONCEPT DESIGNS

3.1 PLUG VALVE CONCEPT

3.1.1 Description

The concept shown in Figures 5 and 6 is essentially the same as the preferred concept except that a Plug Valve, rather than a Rotary Valve, is used in the Bit. The Outer Barrel and its drive system, the Drill Stem, and the Differential Screw of Figure 5 are the same as in Figure 2. Drill Stem rotation and percussion are achieved with a mechanism which is different from the JPL impactor. Motor 2, geared to the Drill Stem, supplies the rotary motion. Motor 1 rotates the Rollers over the face of the Cam through the Percussion Drive Gear and the Drive Tube. The Cam raises the Hammer compressing Spring 2, and then allows the Hammer to impact on the Anvil attached to the Drill Stem. The structure which supports all this mechanism is not shown; however, it would be the same as that shown in Figure 1 and described in Section 2.1.1. The downward force developed by the rotation of the Nut on the Lead Screw is transmitted through the Percussor Housing and the Main Thrust Bearing to the Drill Stem. The Swivel which is mounted above the Percussor is the same as that of Figure 2 except for the addition of an Alignment Groove in the top of the Drill Stem.

The Bit of Figure 6 has a configuration designed to get the Ports closer to the leading point of the Bit than is possible in the Bit of Figure 3. The cross-section of the carbide as shown in Section A-A is chevron-shaped. Again, grooves are provided in the Carbide so that in case one Port should



PLUG VALVE GSATD MECHANISM

FIGURE 5

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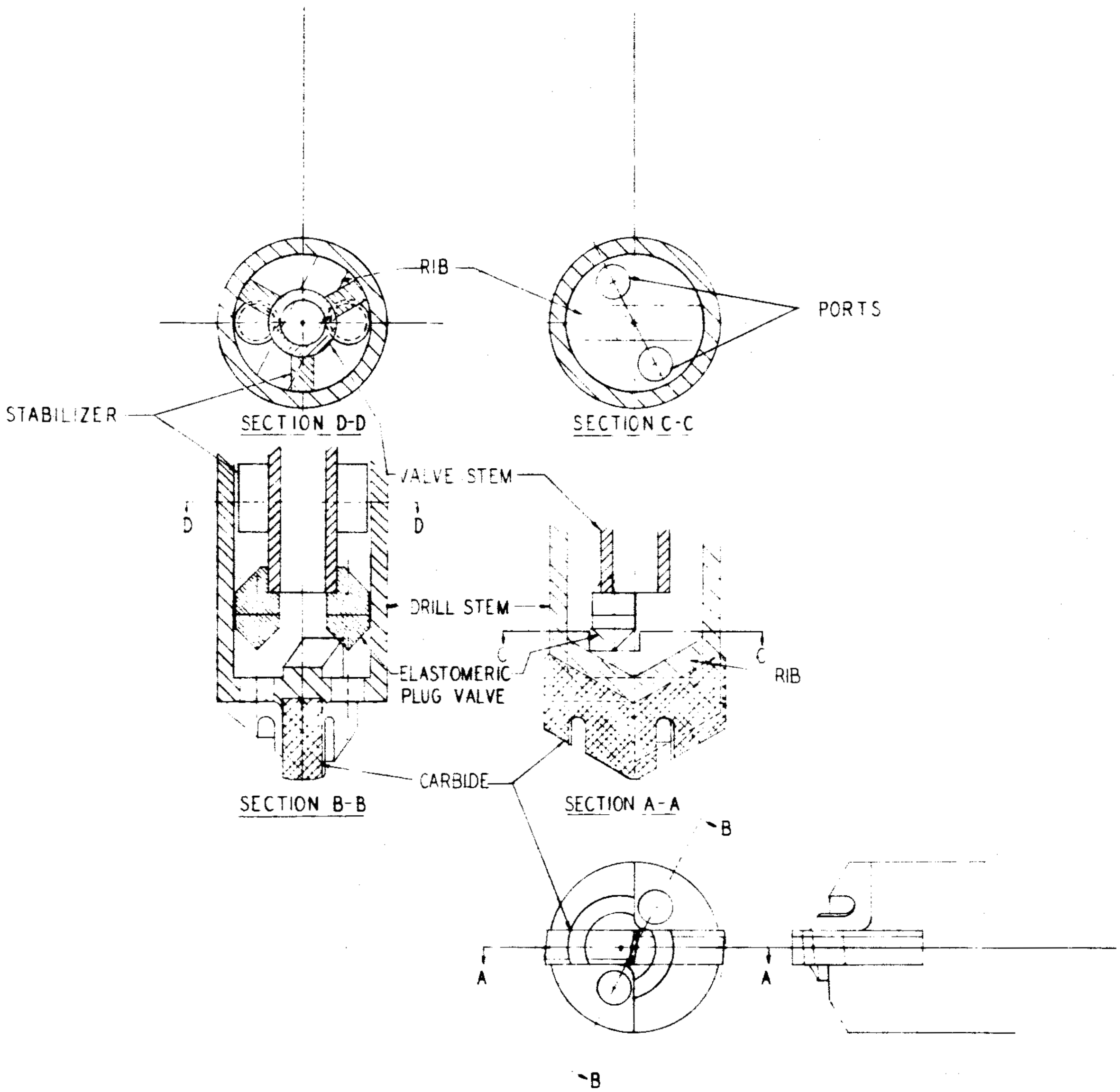

PLUG VALVE BIT
FIGURE 6

RESEARCH DEPARTMENT HUGHES TOOL CO. HOUSTON, TEXAS		
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become plugged, the rock chips would have access to the other Port. A Rib extends across the Bit to provide back-up of the Carbide. The Ports are located in the flat bottom of the Bit Body, one on each side of the Rib. Since the Bit geometry is complicated, it may be easier and more desirable from the standpoint of breakage to make the entire Bit body and cutting blade of sintered Tungsten Carbide using an isostatic press. Such a decision requires further detail design and evaluation.

Elastomeric Plug Valves are attached to the bottom of the Valve Stem which is inside the Drill Stem. In Figure 6 the Valve Stem is shown in its raised position; when it is lowered, the conical portion of the Plug Valves pushes chips to one side and seats in the Ports. The elastomeric properties of the Plug Valves insure a seal even though chips may be trapped between the sides of the Port and the Plug Valve.

The Valve Stem is provided with a Stabilizer at its bottom end and with two Alignment Lugs mating with the Alignment Groove in the top of the Drill Stem, as shown in Figure 5. Above the Swivel, a Solenoid Plunger is attached to the Valve Stem. The Solenoid itself is a latching solenoid, defined on page 19 of Electroid Corporation Catalog 101S as ". . . basically a two coil latching unlatching mechanism. . . . It has a mechanical locking arrangement which holds the solenoid in the retracted position. A switch disconnects the pull coil immediately after locking and connects a release coil. A separate switch is used to release it". This is not a stock item and would have to be custom built. Spring 1 is shown above the Solenoid, but it could be incorporated into the Solenoid housing.

The gas circulation system for transporting the sample from the Bit to the Sample Tray is the same as in Figure 2.

3.1.2 Operation

The operation of this system is acquiring and transporting samples is the same as described in Section 2.2 except for the operation of the Valves. With the Solenoid de-energized and unlatched, Spring 1 forces the Valve Stem down so that the Ports are sealed. When a sample is desired, the Pull Coil of the Solenoid is energized and the Valve Stem rises to the position shown in Figure 5, where it is mechanically latched in place. No further electrical power is necessary to keep the Ports open while the sample is being acquired in the Bit. To close the Valves prior to transporting the sample, the Release Coil of the Solenoid is activated and Spring 1 pushes the Valve Stem down. The Alignment Lugs and Grooves insure that the Plug Valves re-enter the Ports in the correct position.

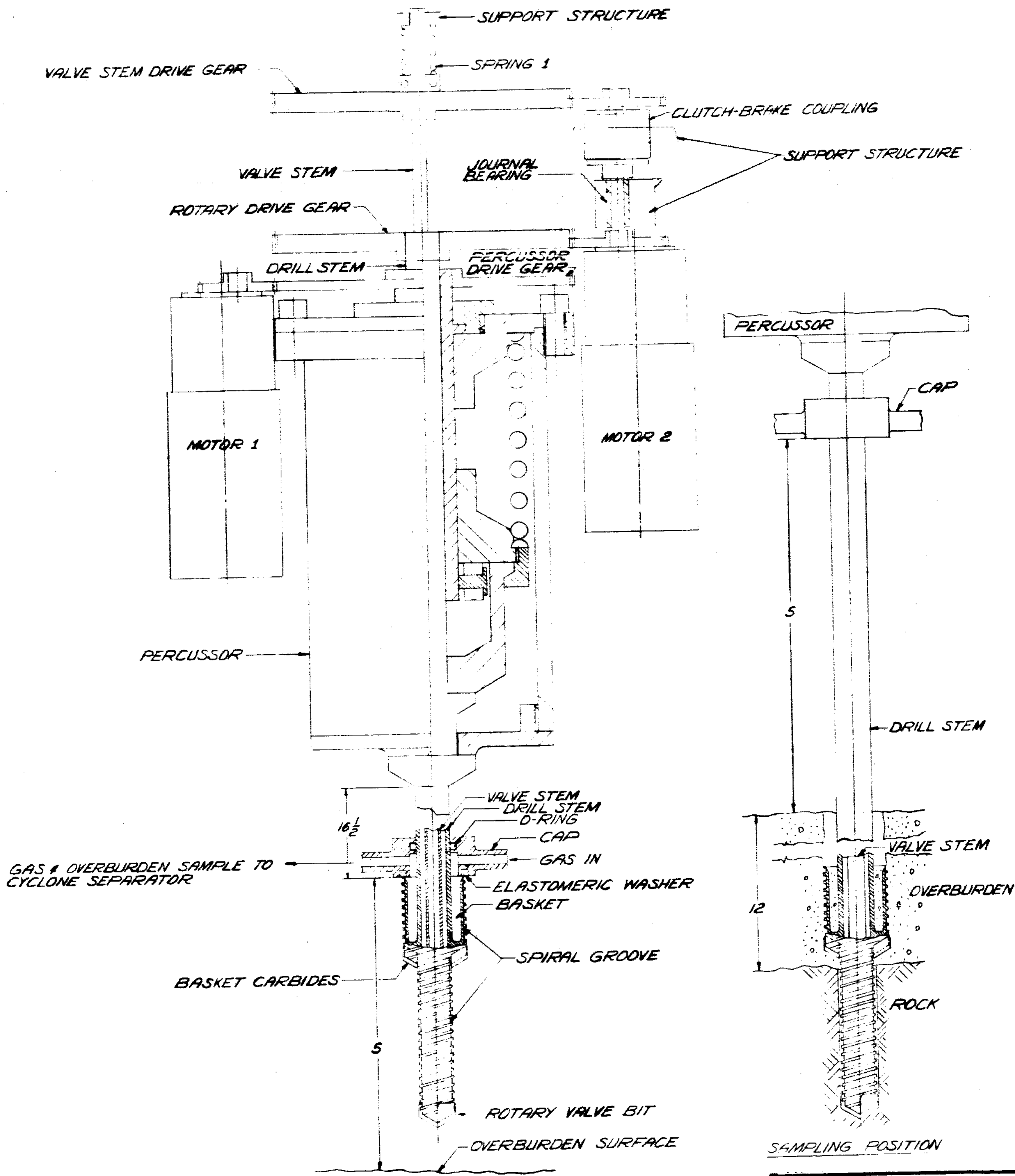
3.1.3 Limitations

Rubble may be trapped between the Port and the Plug Valve as the Plug Valve comes down to seat. If a large piece of rubble is trapped the elastomeric properties of the Plug Valve may not be such that the rubble is completely enveloped. If so, then there is a lost circulation problem. Also, as the Plug Valve comes down, it of necessity pushes some of the acquired sample back through the Port. For these reasons, the Rotary Valve concept is preferred over the Plug Valve concept.

3.2 HTC OVERBURDEN BASKET CONCEPT

3.2.1 Description

The mechanism shown in Figure 7 is a HTC development of the basket concept



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HUGHES TOOL CO.
HOUSTON, TEXAS

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HTC OVERBURDEN BASKET CONCEPT

FIGURE 7

advanced in Foster-Miller's second monthly report (see Figure A-2, page A.1.16 of Appendix A). The Rotary Valve Bit is the Bit of Figure 3. The Basket is a short distance above the Bit and is an integral part of the Drill Stem. Both the Basket and the portion of Drill Stem between the Basket and the Bit have a Spiral Groove on the outer surface. The Basket Carbides will cut clearance for the Basket if the overburden should be cohesive. The Percussor shown is the same one shown in Figure 5 and described in Section 3.1.1, except that Motor 2, which rotates the Drill Stem, has been moved to the top of the Percussor. With Motor 2 in this position, the Clutch-Brake Coupling is attached directly to the output shaft. The rest of the drive train to operate the Rotary Valve is the same as shown in Figure 2 and described in Section 2.1.6. All the mechanism described above is mounted in a movable framework which is supported by the stationary main structure, one of whose members is a lead screw, as shown in Figure 1 and described in Section 2.1.1. Neither the movable nor the stationary framework is shown in Figure 7. The Cap is held by a clamp on the Support Tube and does not move vertically. An O-ring provides a seal between the Cap and the Drill Stem, and the Elastomeric Washer provides a seal between the Cap and the top edge of the Basket.

3.2.2 Operation

The mechanism is deployed to the position shown with the Rotary Valves in the closed position. The appropriate motors are then energized to drill through the overburden. As the Basket goes through the overburden, material flows up the Spiral Groove, over the lip at the top of the Basket, and falls into the Basket. After the Bit has passed the overburden rock interface and acquisition of only rock chips is expected, the Rotary Valves are opened as described in Section 2.1.6. Drilling continues until enough sample is acquired within the Bit; the Rotary Valves are then closed and the mechanism withdrawn from the hole. The Drill Stem is moved vertically until the top of the Basket seats in the Elastomeric Washer. Gas is then admitted through the Cap to the Basket interior; the overburden sample is picked up by the gas, carried to a Cyclone Separator, and deposited on a Sample Tray. To collect the rock sample, a tray must be positioned under the bit, the Rotary Valves opened, and Motor 1 energized, if necessary, to vibrate the sample out of the Bit. Although it is not intended that the Basket Carbides do any drilling in the rock (see "Sampling Position", Figure 7), if the overburden is a thin layer, the Basket may be drilled down into the rock far enough to allow overburden to fall into it.

3.2.3 Limitations

Although the "Basket" idea appears to be a very simple way of getting a sample from a deep layer of overburden, difficulties arise in design of a complete mechanism. The gas circulation system of the preferred concept is eliminated by using the "Basket" idea, but another gas circulation system (as shown in Figure 7) must be used or the entire mechanism must be turned over and shaken in order to get the overburden sample into a sample tray. It is not desirable to depend on lunar gravity and vibration to transfer overburden samples from the Basket, or for that matter, rock samples from the Bit interior, because of the possibility of vacuum welding. In the preferred concept, sample particles are surrounded by a selected gas atmosphere immediately upon acquisition thereby eliminating this objection. Another limitation is that the possibility of rock sample contamination by overburden is greater in this case than in the preferred concept, and acquisition of under-dense overburden is more doubtful.

3.3 FOSTER-MILLER RECOMMENDED CONCEPTS

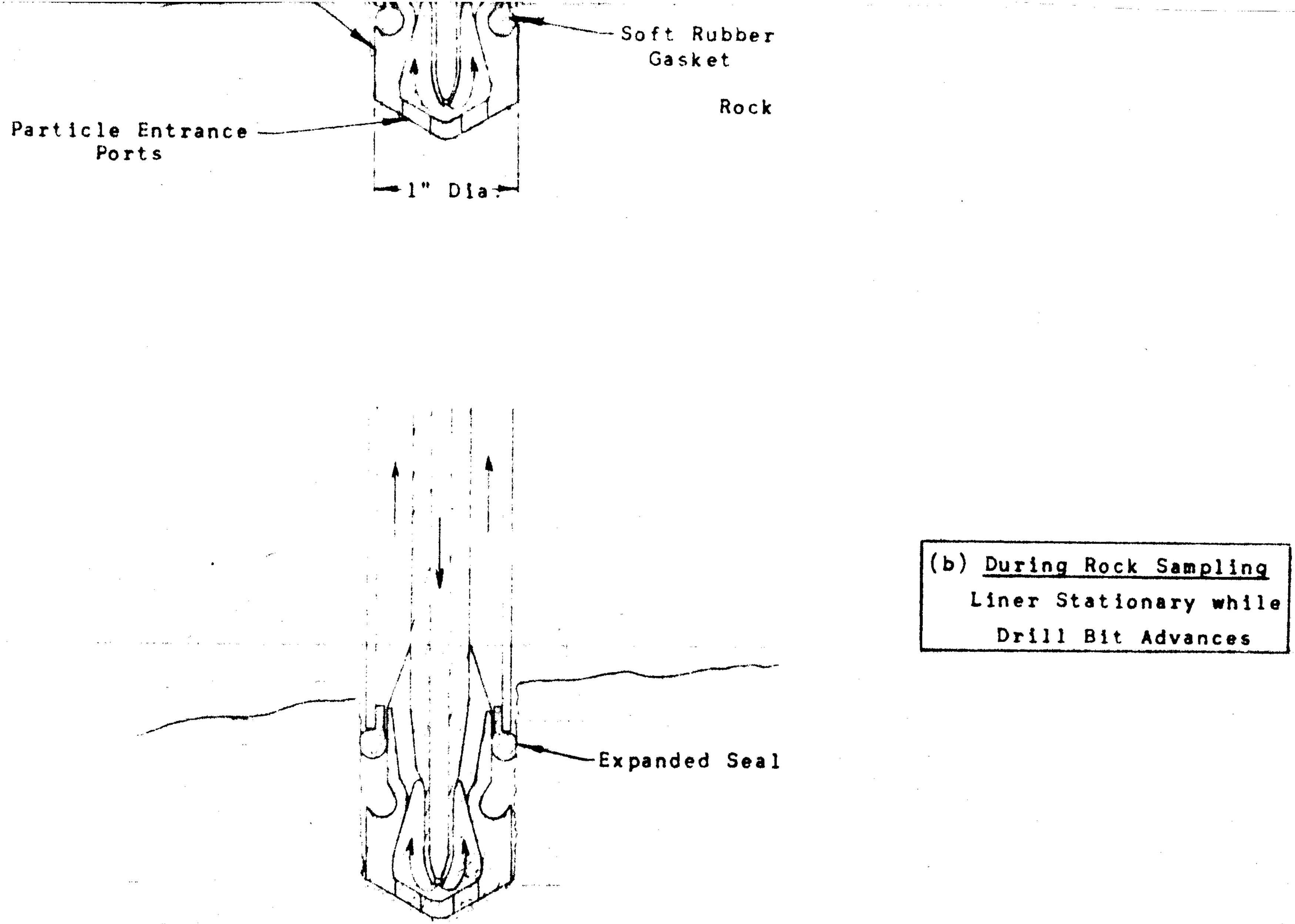
The concepts discussed briefly in this sub-section were recommended in Progress Report #3 from Foster-Miller. This report (see Appendix A) contains an evaluation of their various concepts and the reasons for their recommendations. The following paragraphs include a further evaluation of these concepts based on discussions which occurred during the preliminary and final design review.

3.3.1 Continuous Gas Transport

Concept FM-4 is shown in Figure 8. In principle, it is the same as the concept discussed in Section 2. The only differences are: a positive overburden seal is provided, and the circulation system is not closed. The cam-operated seal will help prevent contamination of the rock sample; however, the lack of a closed gas circulation system is enough to suspend development of this concept. Fissured rock would result in lost circulation and prevent any sample from reaching the Cyclone Separator. Similarly, in a permeable overburden, circulation would be lost and no sample could be retrieved. In under-dense, non-cohesive overburden it appears extremely doubtful that any sample would negotiate the port passages into the interior of the bit, particularly with continuous gas flow.

3.3.2 Batch Collector

Concept FM-9 is shown in Figure 9. Here a rotating auger is used to



Continuous Gas Transport Concept (FM-4) with Expanding Overburden Seal

Figure 8

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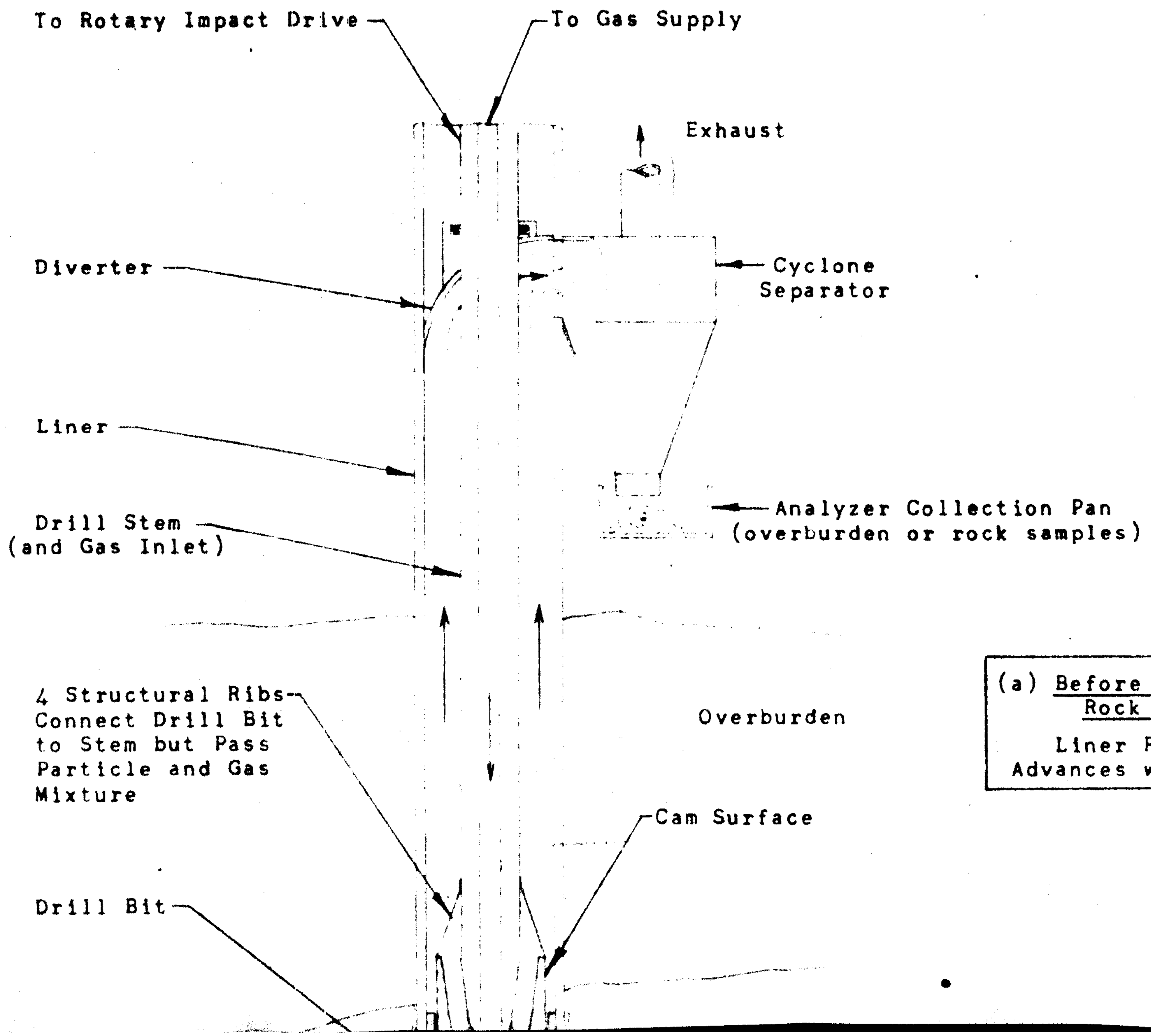
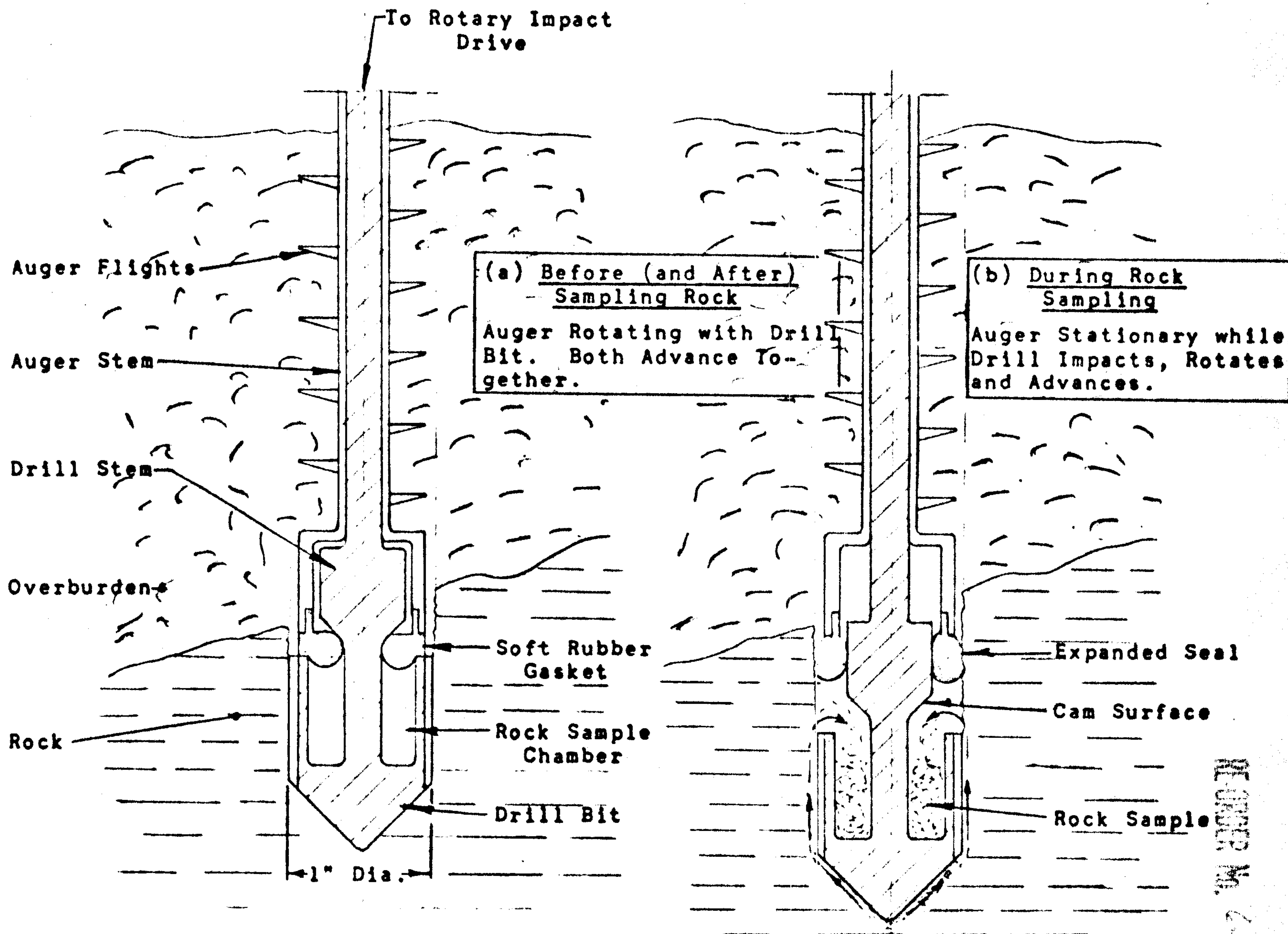


(a) Before (and After) Rock Sampling

Liner Rotates and Advances with Drill Bit



Batch Collector Concept (FM-9) with Overburden Auger and Expanding Seal

Figure 9

acquire and transport the overburden sample, and a Rock Sample Chamber similar to the Basket of Figure 7 is used for the rock sample. A cam-operated gasket provides a positive seal between the overburden and the place where the rock sample is acquired. Although the rock sample is acquired and transported satisfactorily in this concept, difficulties arise in transferring the sample to a tray for analysis. Some other device, such as the Cap shown in Figure 7, will be required to get the sample from the Rock Sample Chamber to the Sample Tray; the configuration of Figure 9 makes the use of such a device very difficult. For this reason no further development was done on the rock sampling aspects of Concept FM-9. JPL is currently investigating the use of a screw conveyor or auger for sampling; thus no further development was done on the over-burden sampling aspects of Concept FM-9.

Section 4

CONCLUSION

A large number of concepts were proposed. Concept generation was broad in scope with no constraints being placed on method other than possible ultimate weight, space, power, and task requirements. The feasibility of each concept was evaluated, both individually and in possible combination with others.

A single sampling concept was selected as being the most feasible approach by HTC and JPL engineers. This concept was developed into a preliminary design of a breadboard model Geologic Sample Acquisition and Transport Device.

The selection of the preferred concept was based on engineering judgment, experience, and study of the state-of-the-art in related fields. Actual feasibility can be determined only by detailed design, fabrication, and testing.

APPENDIX A

FOSTER-MILLER CONCEPTS AND REPORTS

A.1 - Progress Report #2 of 9 July 1965. Concepts A-1 through A-22.

A.2 - Progress Report #3 of 17 August 1965. Concepts FM-1 through FM-9 (Further Developments of Best Concepts by FM).

Note: Progress Report #1 is not included inasmuch as work done in this period was fully reported in Reports #2 and #3.

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APPENDIX A.1

PROGRESS REPORT #2

FOSTER-MILLER ASSOCIATES, INC. to
HUGHES TOOL COMPANY
9 JULY 1965

1. Description of Work Performed During This Reporting Period

1.1 Program Direction

During this period effort was concentrated on accomplishing the following work:

(1) generation of concepts to supplement those described in the last reporting period;

(2) classification of generated concepts to facilitate systematic evaluation, and minimize the possibility of overlooking concepts;

(3) selection of the most promising concepts for further investigation.

The results of this effort are discussed in the following subsections.

1.2 Generation of Additional Concepts

Figures A-13 through A-22 of Appendix A, describe additional concepts generated by our staff during this reporting period. For convenience, all concepts generated to date have been included in Appendix A.

1.3 Classification of Concepts

The basic tasks required to accomplish the mission (as defined in Section 2.1 of the Foster-Miller Progress Report Number 1) are shown on Classification Chart Number 1. Various methods to accomplish tasks 1, 3, and 4 are shown in Classification Charts Numbers 2, 3, and 4, respectively. The assumption was made that task 2 will be performed with a device similar to the JPL Rotary Impact Drill.

Basic tasks are defined as follows:

Task 1 - Gaining access to the rock is the process of making the rock layer sufficiently accessible to permit fragmentation and acquisition.

Task 2 - Fragmentation of the rock using a rotary impact drill.

Task 3 - Acquisition is the process of acquiring sample rock fragments at the point at which they are produced by the drill.

Task 4 - Transport is defined as conveying the particles from the point of acquisition to a point slightly above the surface.

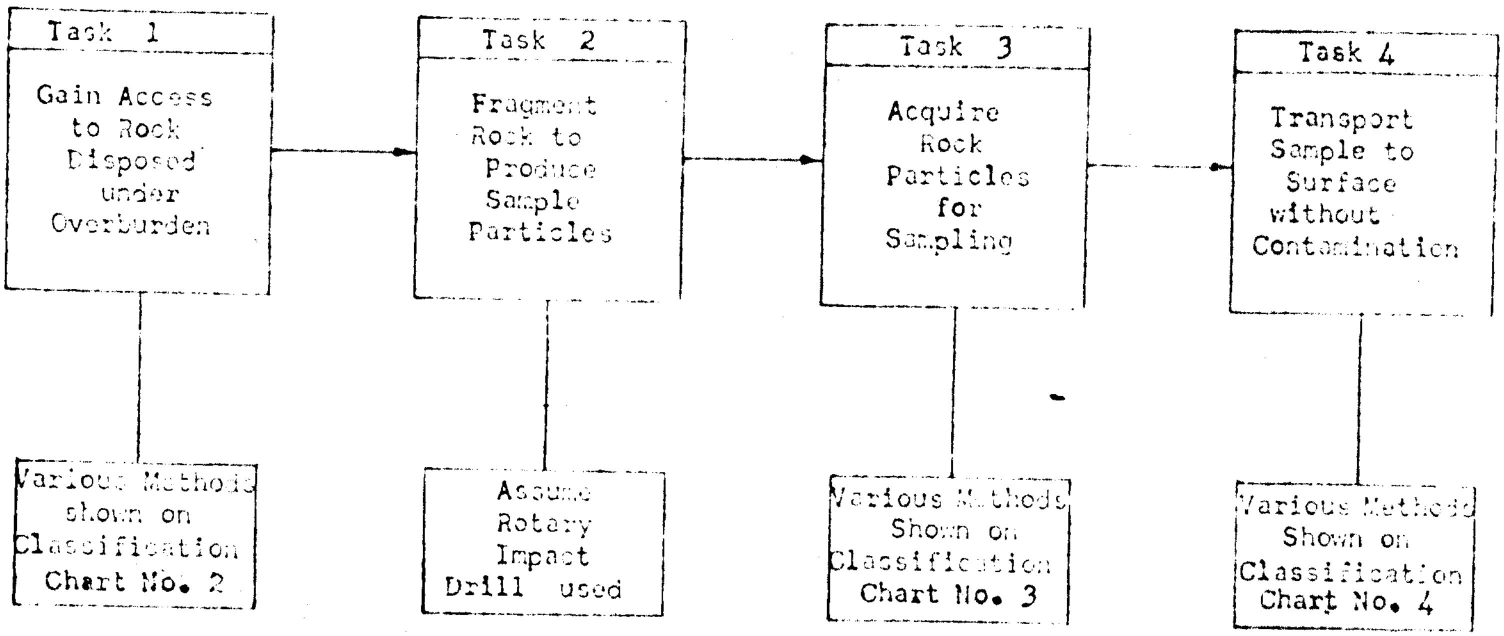
The Numbers appearing under certain "Blocks" in Charts 2, 3, and 4, refer to the Figures in Appendix A. The generated concepts are thus classified according to the particular method each employs to accomplish each basic process task.

1.4 Selection of the Most Promising Concepts

The first step in the selection process is the elimination of obviously poor methods to accomplish each task. Concepts utilizing the best methods to accomplish each task are likely to be the most promising

Classification Chart Number 1

Tasks Required to Accomplish Geological Sample Acquisition Mission

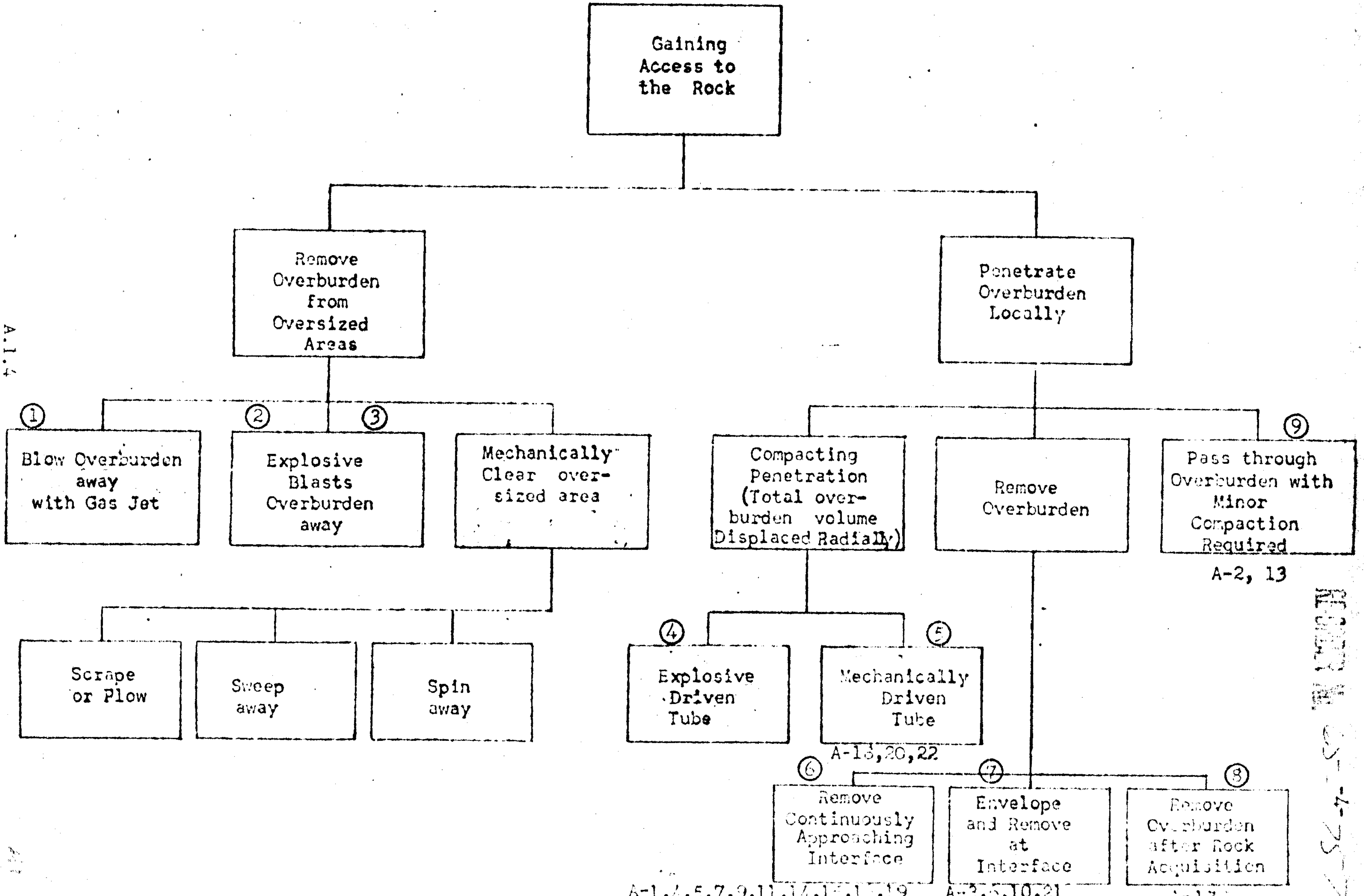


Notes: 1. The same method may be used to accomplish more than one task. For example a bucket conveyor might be used to gain access to the rock, acquire a sample and transport it to the surface.

2. Combinations of methods may be used to accomplish the mission. For example, gas jets might be used for sample acquisition in combination with mechanical transport of the sample to the surface.

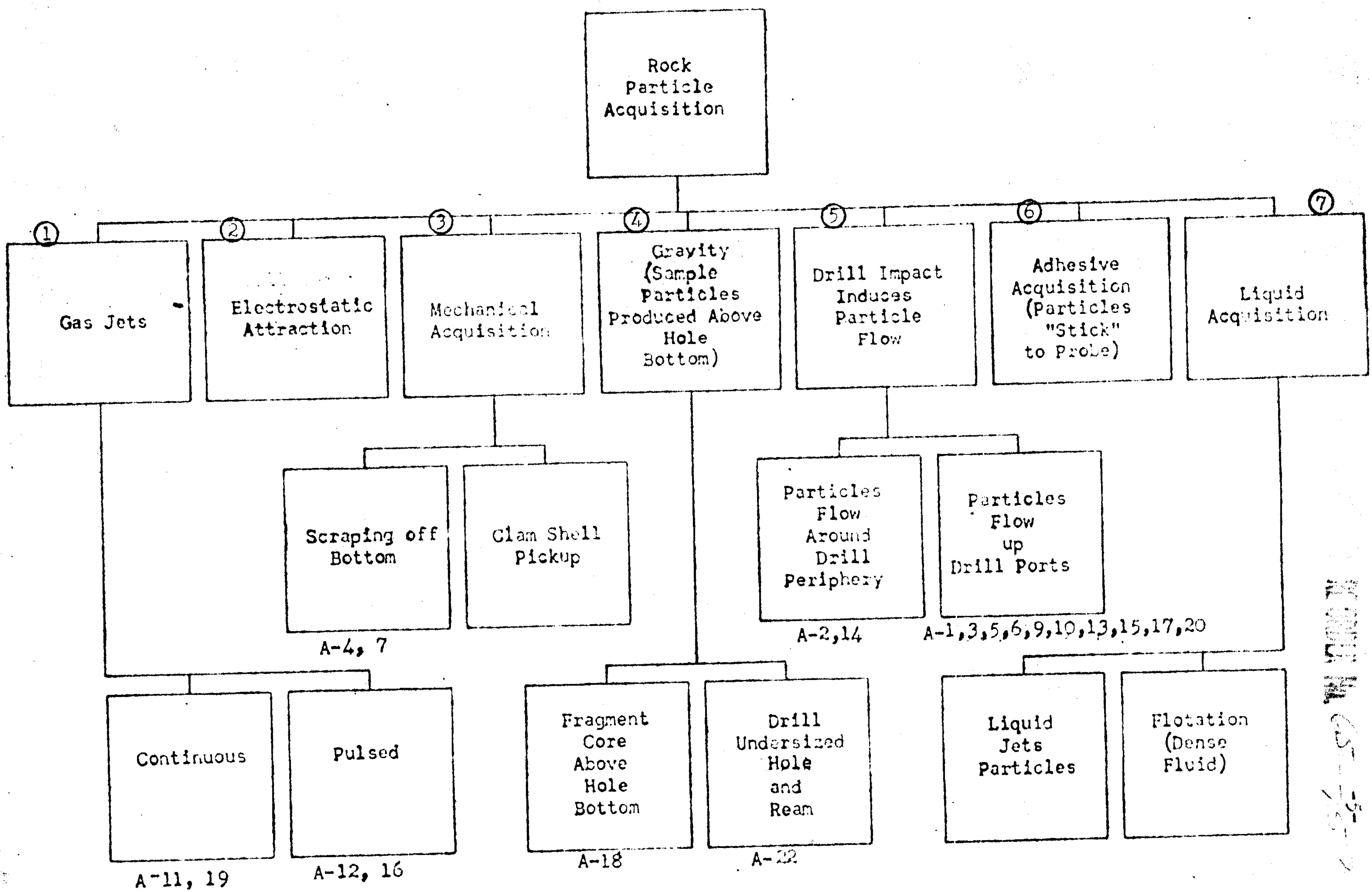
Classification Chart Number 2

Methods to Gain Access to the Rock Disposed under the Overburden Layer



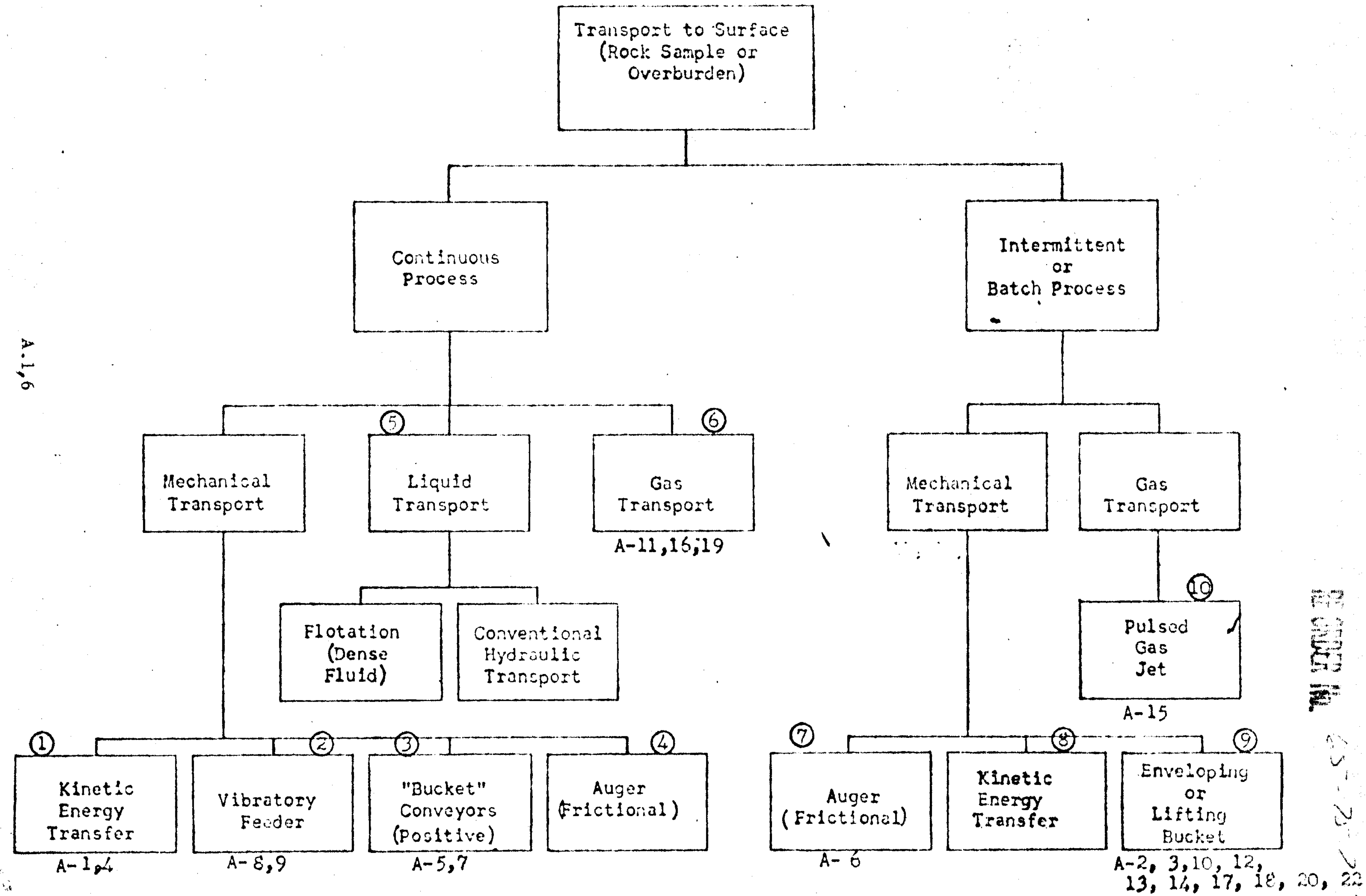
Classification Chart Number 3

Methods to Acquire Rock Particles for Sampling



Classification Chart Number 4

Methods to Transport Particles (Overburden or Rock Sample) to Surface



A.1,6

concepts to accomplish the mission, provided that serious deficiencies do not result from combining incompatible methods to form the complete system.

1.4.1 Selection of the Most Promising Methods to Gain Access to the Rock Layer (Task 1)

For convenience, methods to accomplish this task are identified on Classification Chart Number 2 by the circled numbers appearing above the "Blocks".

The disposition of these methods is shown in Table I.

Those concepts which involve removal of the overburden continuously during penetration and those devices which "pass through" the overburden are considered the most promising methods to gain access to the rock interface.

1.4.2 Selection of the Most Promising Methods to Acquire Rock Particles for Sampling (Task 3)

Here again the circled numbers appearing above the "Blocks" on Chart Number 3 serve to identify the methods to accomplish this task. The disposition of these methods is shown in Table II.

As shown in Table II, gas scavenging jets, particle flow due to drill impact, and the gravity concept are considered the most promising particle acquisition methods.

1.4.3 Selection of the Most Promising Methods to Transport Particles to the Surface (Task 4)

Table III describes the disposition of the various methods to transport particles shown on Chart Number 4.

Table I

Disposition of Methods to Gain Access to Rock Layer Under the Overburden

Method Number (See Chart 2)	Comments	Disposition
1	Overburden may be cohesive requiring a huge jet energy level to clear the area.	Eliminated
2	Size of explosive charge depends on overburden properties; shock and debris may damage spacecraft.	Eliminated
3	Energy and force levels required will be excessive if overburden is cohesive. On the other hand an excessive volume of a free flowing overburden would have to be removed.	Eliminated
4	If overburden is hard to penetrate a large charge would be needed. If easy to penetrate tube would rebound excessively. Shock may damage spacecraft.	Eliminated
5	High force level may be required in cohesive overburden, and large retrieval force required due to friction.	Eliminated
6	Lower peak power and force levels required as removal is continuous; Control simplified by continuous process. Device need only advance and retract once to complete entire mission.	Retained
7	Liner required while removing to prevent "cave in" if overburden not cohesive. Device must penetrate, remove overburden and re-enter (to acquire rock) increasing control complexity.	Eliminated
8	Difficult to avoid mixing of overburden with rock sample as both removed together. Requires check valve operating in dirty environment.	Eliminated
9	Requires only minor compaction as overburden material can "fill in" above bit. May be feasible if stem diameter can be kept small. Removal of device easier than 4 and 5 as friction forces lower.	Retained

Table II

Disposition of Methods to Acquire Rock Particles for Sampling

Method Number (See Chart 3)	Comments	Disposition
1	Offers possibility of sweeping particles off hole bottom reliably. Small particle size and small volume of sample required make gas supply penalties tolerable. Compatible with impact bit. Fissures might cause failure of some versions.	Retained
2	Dependent on material characteristics in high vacuum. Low confidence level that method will operate.	Eliminated
3	Difficult to scrape irregular surface. Incompatible with impact bit.	Eliminated
4	Good confidence level that particles will be acquired if produced as shown. However, an excessive volume of rock may have to be drilled to obtain a small sample.	Retained
5	Simple and compatible with rotary impact drill. Tests show that particles will flow a short distance at least.	Retained
6	Comment on Method 2 applies.	Eliminated
7	Liquids vaporize in vacuum. Excessive weight penalty - No advantage over gas transport.	Eliminated

Table III

Disposition of Methods to Transport Particles to the Surface

Method Number (See Chart 4)	Comments	Disposition
1	Some configurations appear feasible and simple. Low power level required.	Retained
2	Transport depends on particle properties, such as friction coefficient, density, etc., low confidence level. Some particle sorting may occur.	Eliminated
3	Too complex, too many moving parts in contact with transported material.	Eliminated
4	Depends on friction properties of material in vacuum to transport material. Clearing auger to prevent sample contamination difficult.	Eliminated
5	Liquids vaporize, severe weight penalty separation problems, gas can do same job more reliably.	Eliminated
6	Compatible with impact drill;weight penalty not excessive because of small particles and small volume of material to be transported. Very compatible with gas acquisition.	Retained
7	Same comment as method 4 above.	Eliminated
8	No advantage over method 1 and increased peak power requirements.	Eliminated
9	Some configurations appear feasible. Positive prevention of sample contamination possible. Positive transport method if material successfully acquired.	Retained
10	May offer weight saving over method 6 due to intermittent use of gas.	Retained

As shown in Table III, continuous kinetic energy transfer, intermittent and continuous gas transport, and batch type mechanical enveloping (or lifting bucket) methods are considered the most promising particle transport methods.

1.4.4 Characteristics of the Most Promising Concepts

In the previous three sections the most promising methods to accomplish each basic task were selected. Those concepts which utilize these preferred methods to accomplish each task are considered to offer the most potential. Table IV lists these concepts and shows the preferred method by which each task is accomplished.

In general the most promising concepts utilize compatible methods to accomplish the tasks. Thus those concepts using a continuous (gas or kinetic energy transfer) transport method use the continuous overburden removal method to gain access to the rock. Likewise the concepts using a batch transport method are compatible with the "passing through" method of gaining access to the rock. Systems using the gas acquisition method use gas transport to convey the sample to the surface. This is not surprising since in the conceptual process the engineer tends to combine compatible processes and reject incompatible combinations.

1.5 Tentative Conclusions

1.5.1 Foster-Miller Associates is continuing on the assumptions that: (a) the rotary impact drill will be used in the mission; (b) fragmented rock will "flow" up holes or flutes in the drill bit as the drill impacts; (c) the drill will penetrate consolidated and unconsolidated overburden as well as hard rock.

Table IV

Characteristics of the Most Promising Concepts

Concept Number (See Appendix A for Sketches)	Preferred Method to Accomplish Each Task		
	Method of Gaining Access (Penetrating Overburden)	Method of Acquiring Particles	Method of Transporting Sample to the Surface
A- 1	Continuous Removal	Particle Flow	Continuous Kinetic Energy Transfer
A- 2	"Passing Through"	Gas Jet	Batch Type
A-11	Continuous Removal	Gas Jet	Gas Transport
A-13	"Passing Through"	Particle Flow	Batch Type
A-14	Continuous Removal	Particle Flow	Batch Type
A-15	Continuous Removal	Particle Flow	Batch Type
A-16	Continuous Removal	Gas Jet	Gas Transport
A-18	None Provided as yet	Gravity	Batch Type
A-19	Continuous Removal	Gas Jet	Gas Transport
A-22	None Provided as yet	Gravity	Batch Type

1.5.2 The concepts listed in Table IV appear to offer the most potential of those generated by Foster-Miller Associates. Preliminary analysis indicates that some of them are particularly attractive because of their simplicity, small number of moving parts, low power consumption and potentially low weight.

1.5.3 A more detailed definition and evaluation of the remaining concepts is required to permit meaningful selection of the best few concepts.

2. Effort Planned for the Next Reporting Period

During the next (and final) reporting period the remaining concepts will be investigated in more detail and modified as necessary. The best two or three concepts will be recommended for further development.

In addition, the final report will be submitted. This report will include material from the progress reports along with a description of the work accomplished during the forthcoming reporting period.

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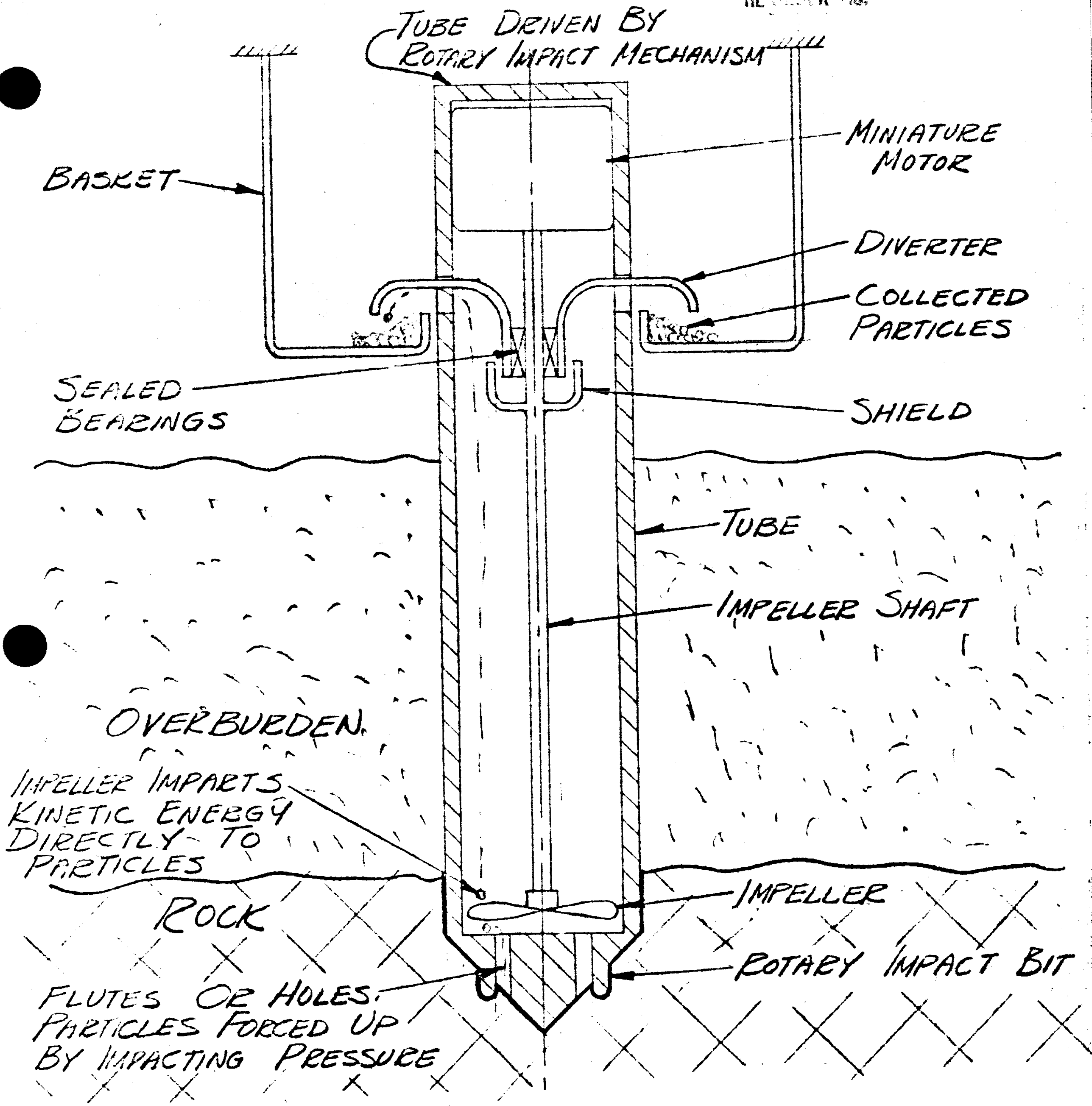

IMPELLER TRANSPORT CONCEPT

FIGURE A-1

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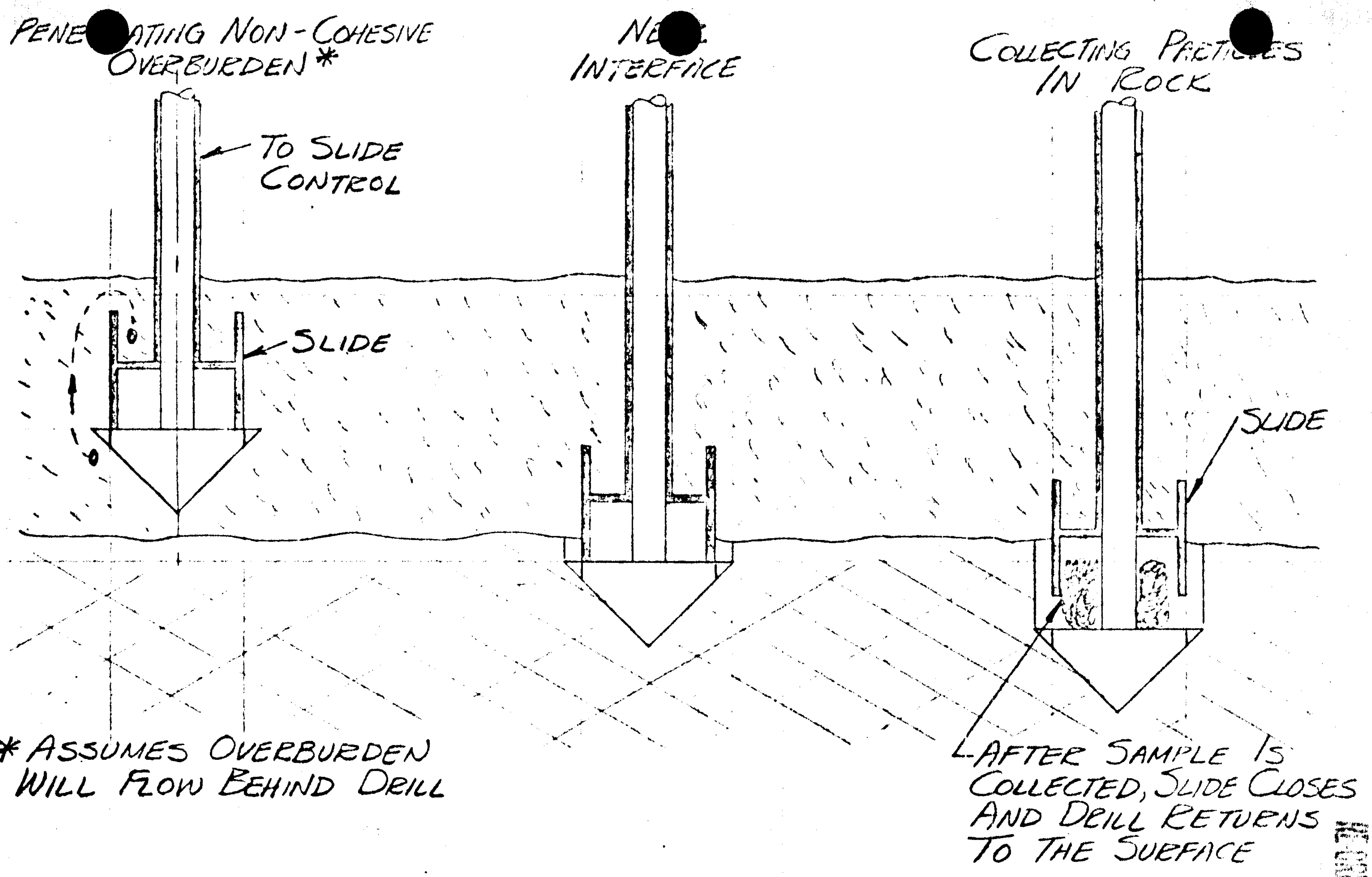

BATCH COLLECTOR CONCEPT

FIGURE A-2

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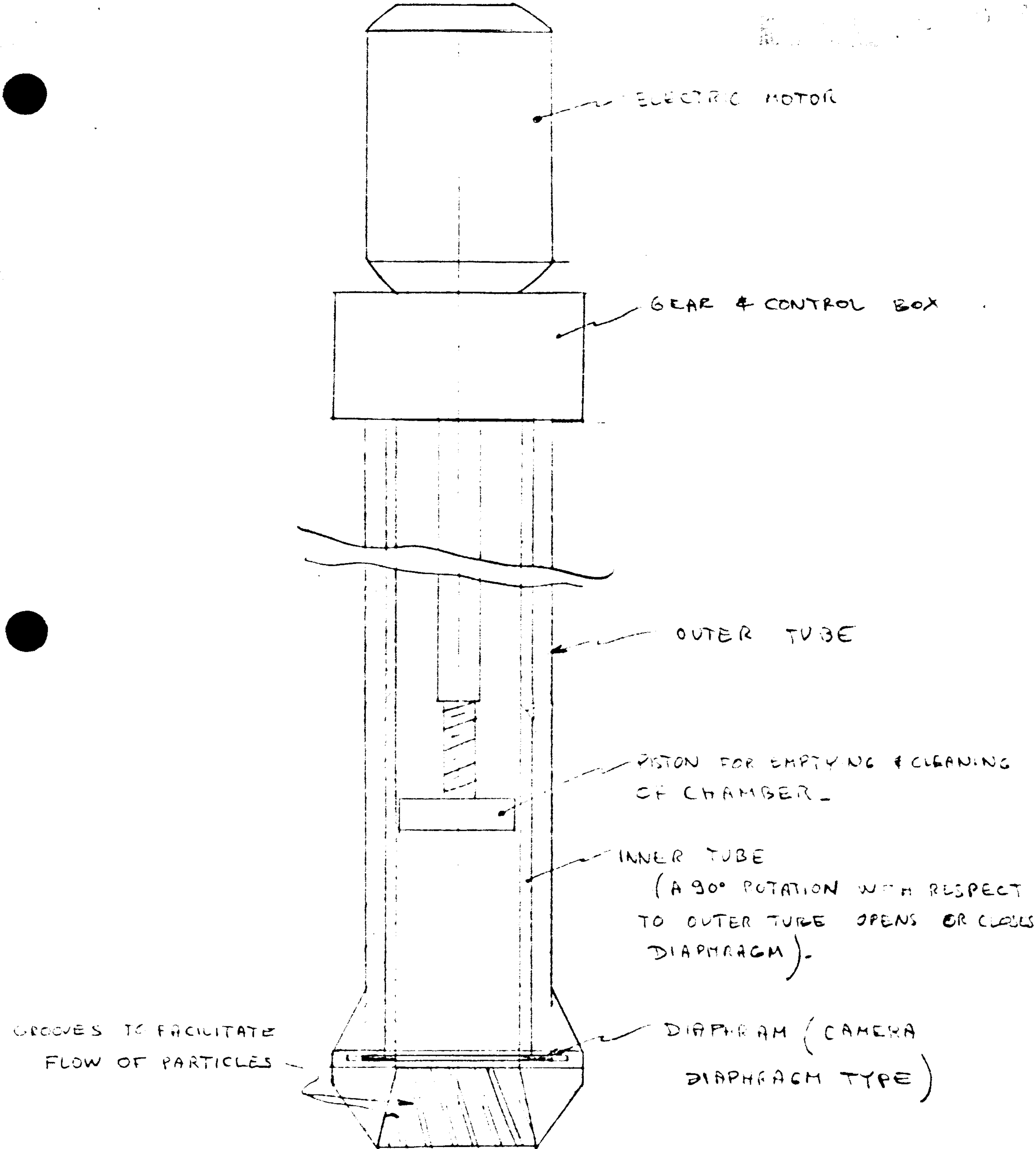

-DIAPHRAGM CHECK VALVE CONCEPT-

FIG. A-3 A.1.17

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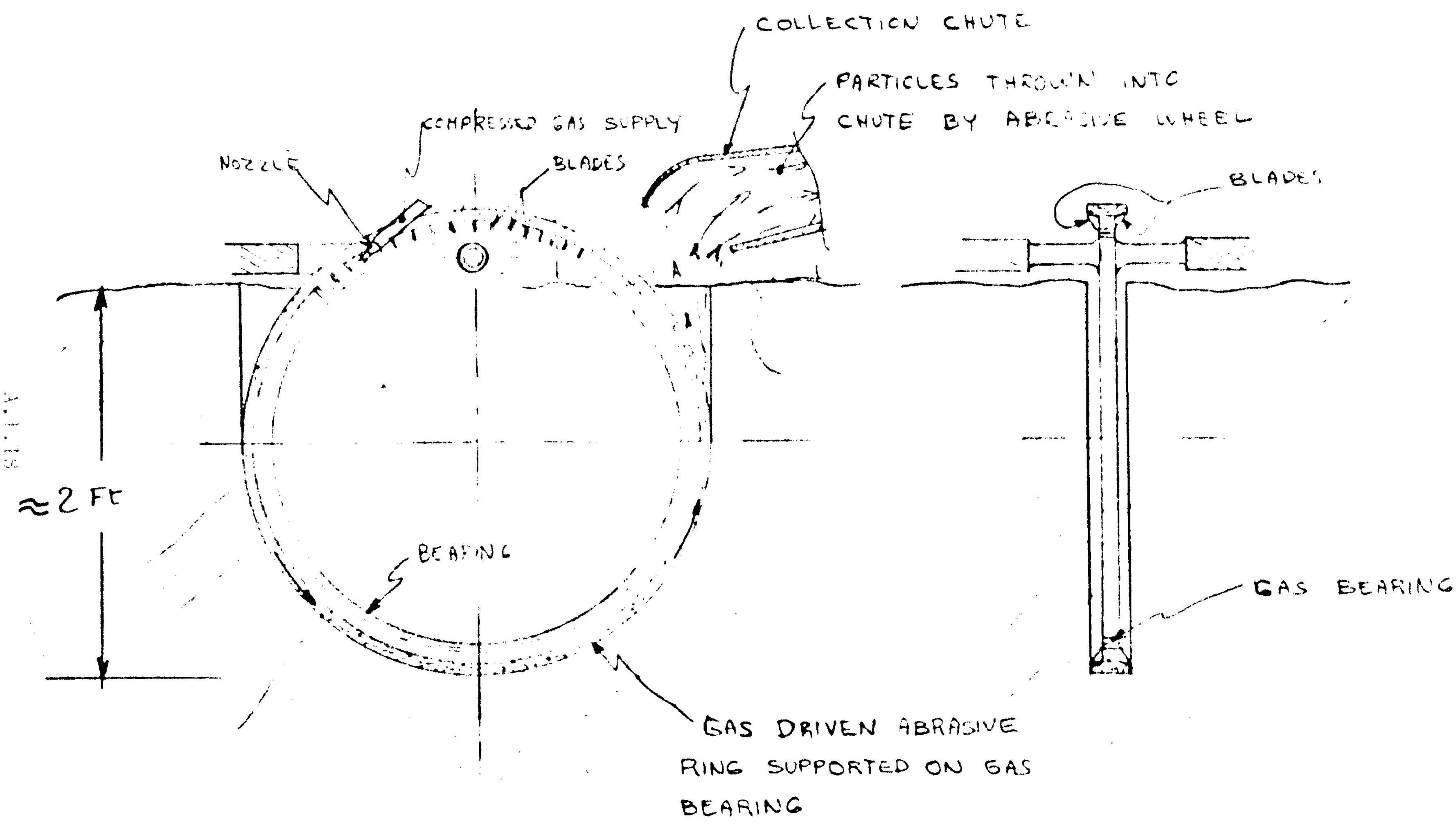

- ABRASIVE WHEEL CONCEPT -

FIG. A-4

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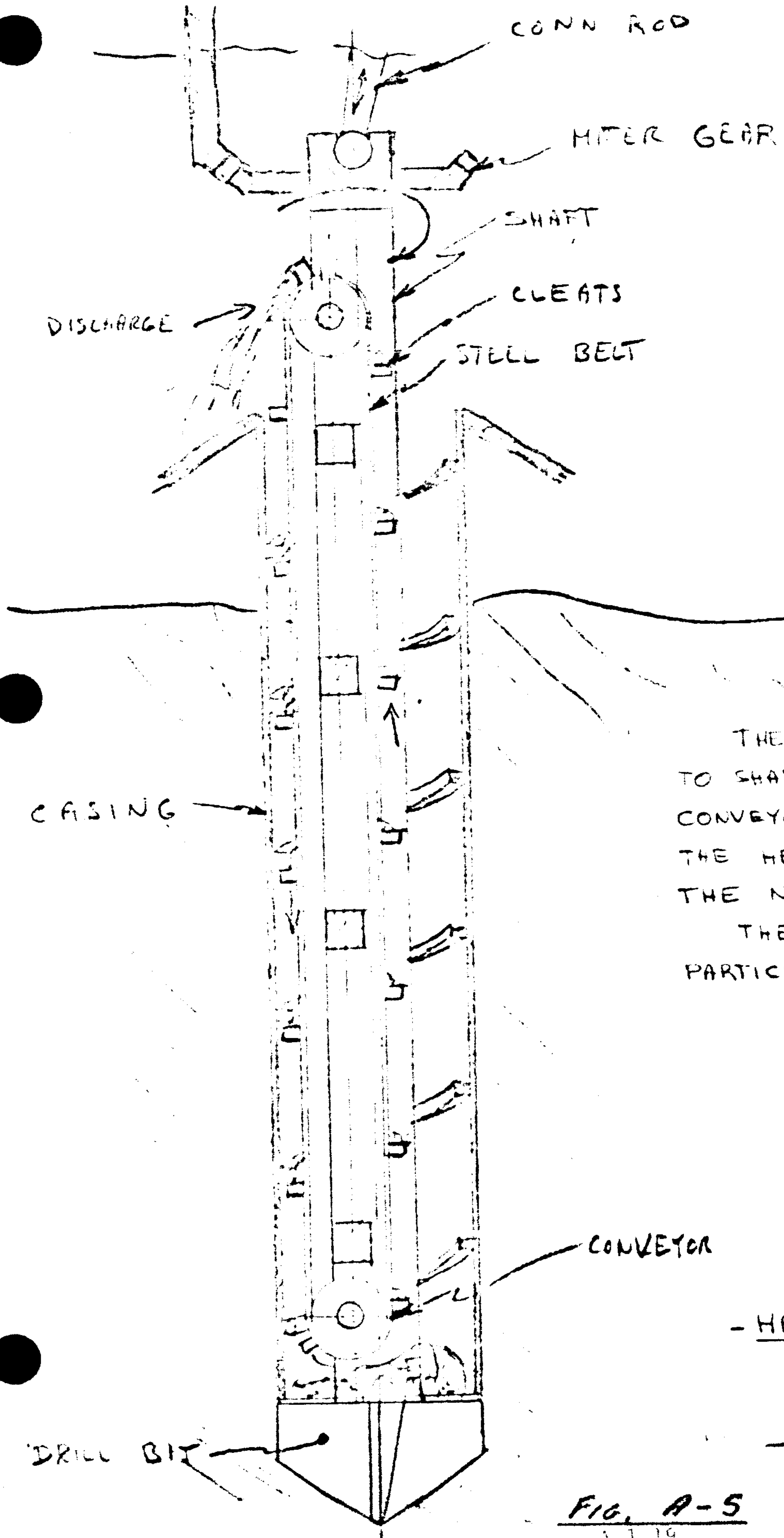


THE CONVEYOR FRAME IS FIXED TO SHAFT - AS THE SHAFT TURNS, THE CONVEYOR CLEATS ARE ADVANCED BY THE HELICAL SURFACES ATTACHED TO THE NON-ROTATING CASING.

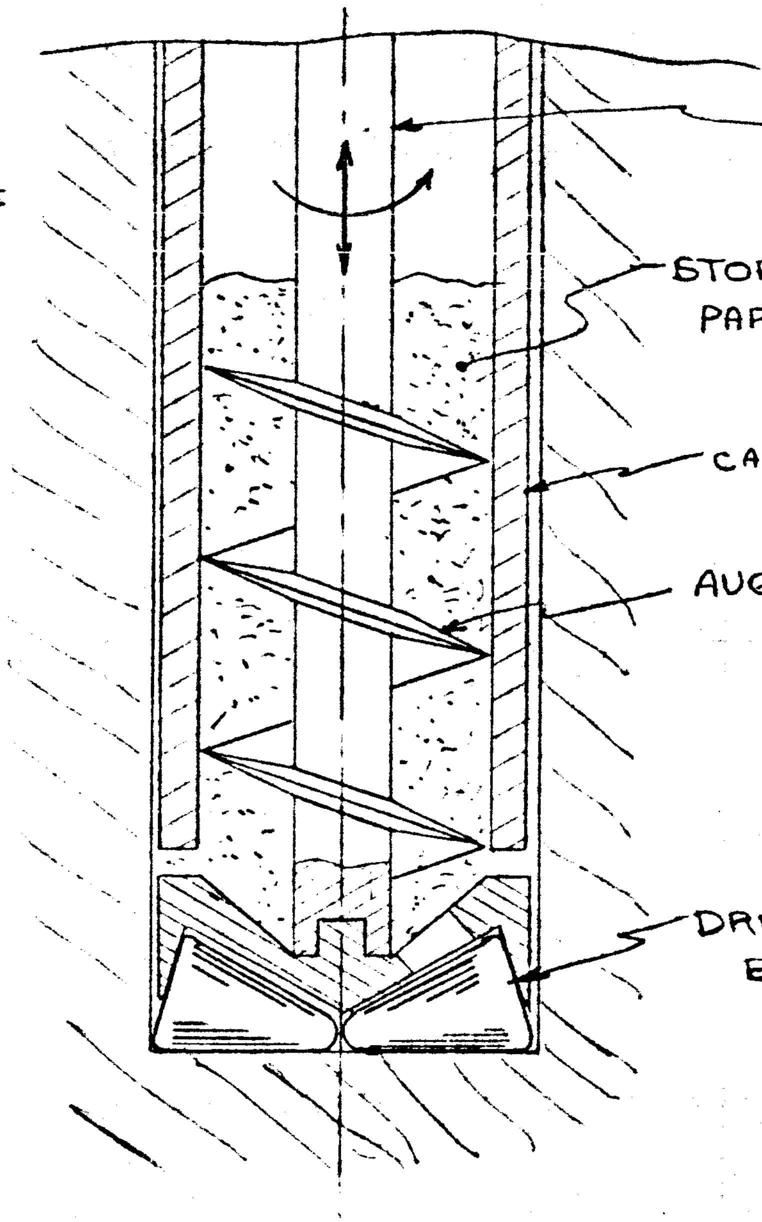
THE CLEATS TRANSPORT THE PARTICLES.

- HELICAL CLEAT CONVEYOR -

- FOSTER - MILLER ASSOCIATES -
WALTHAM, MASS.
YSF - May 21, 65

FIG. A-5

CASING & STEM ARE RETRACTED TO CLEAR AUGER FLIGHTS AT THE SURFACE.



– BATCH TYPE AUGER –

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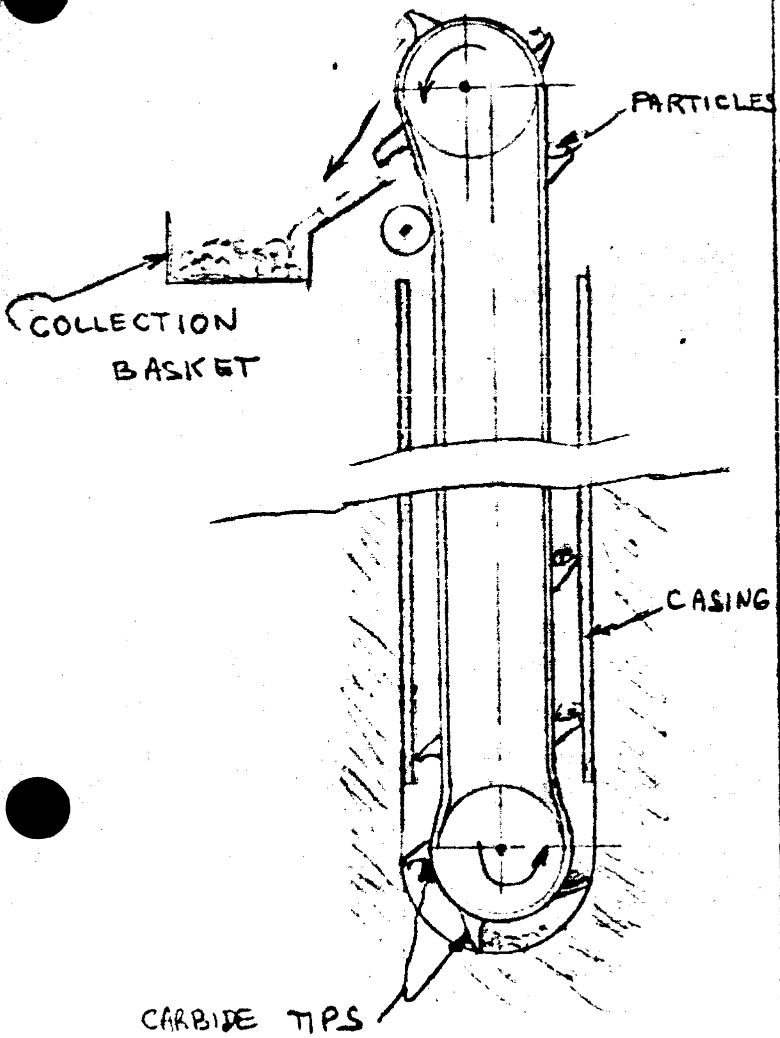
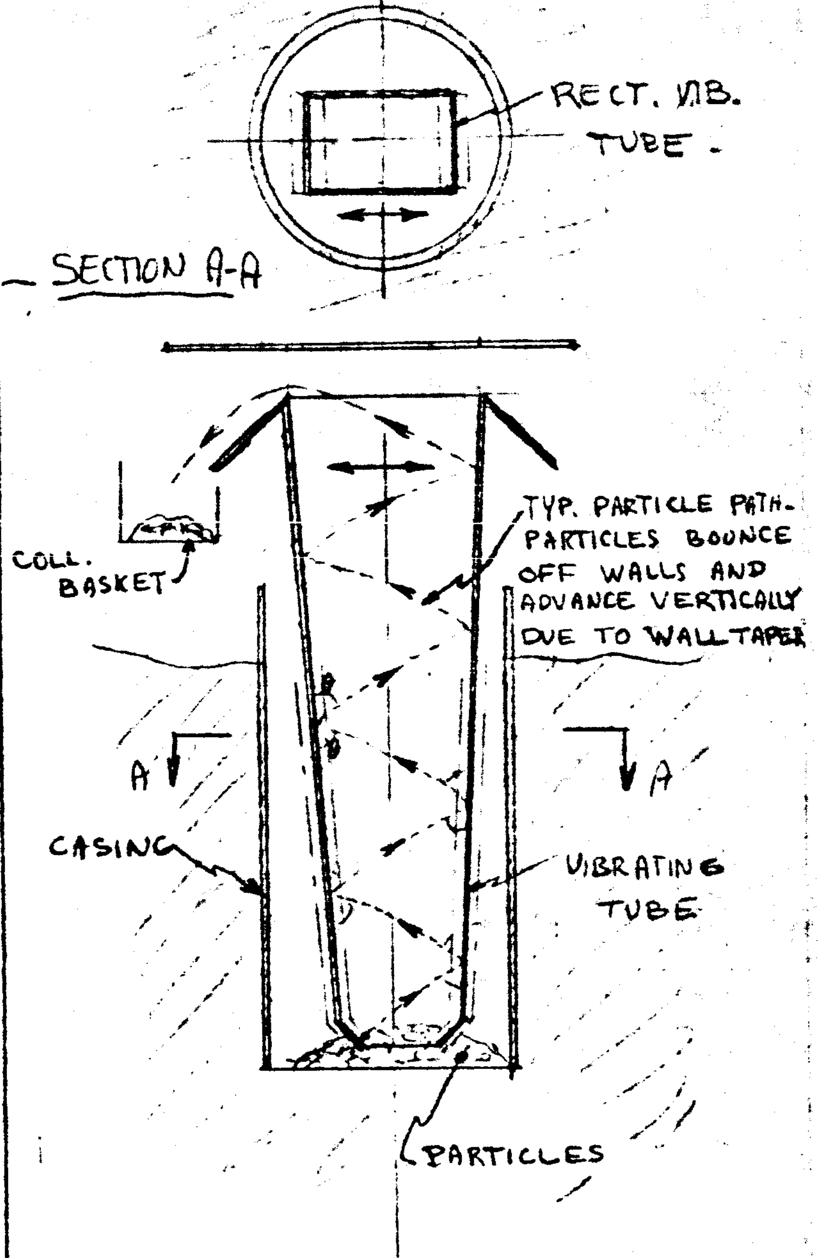
FIG. A6



- INTEGRAL CONVEYOR AND CUTTER CONCEPT -

- Fig. A-7 -



- VIBRATING TAPERED TUBE CONCEPT -

- Fig. A-8 -

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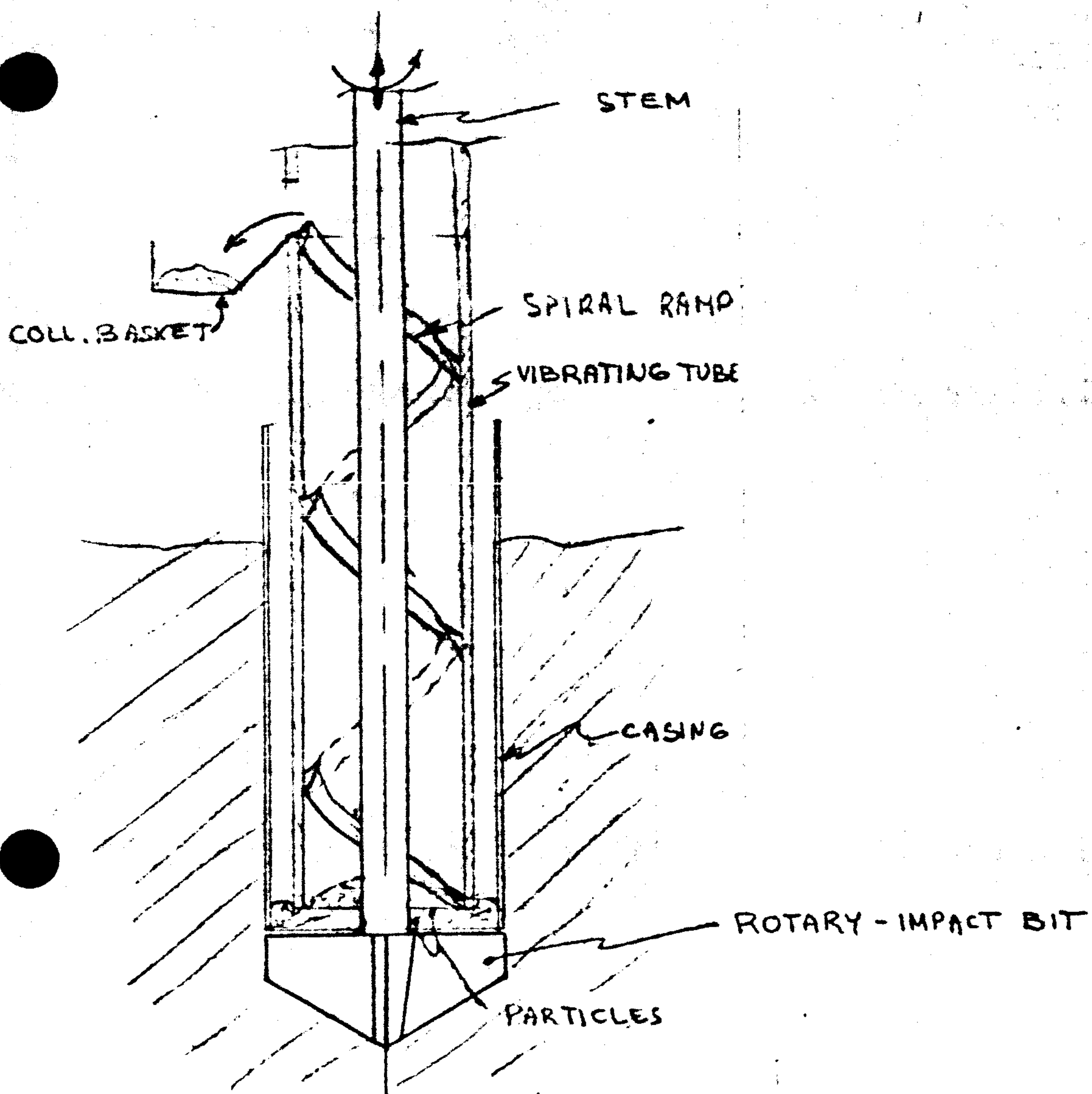

THE TUBE VIBRATES WITH A MOTION SIMILAR TO "SYNTRON" TYPE PARTS FEEDER - THE PARTICLES ADVANCE SLOWLY UP THE SPIRAL RAMP.

-VIBRATORY PARTS FEEDER CONCEPT-

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FIG. A-9

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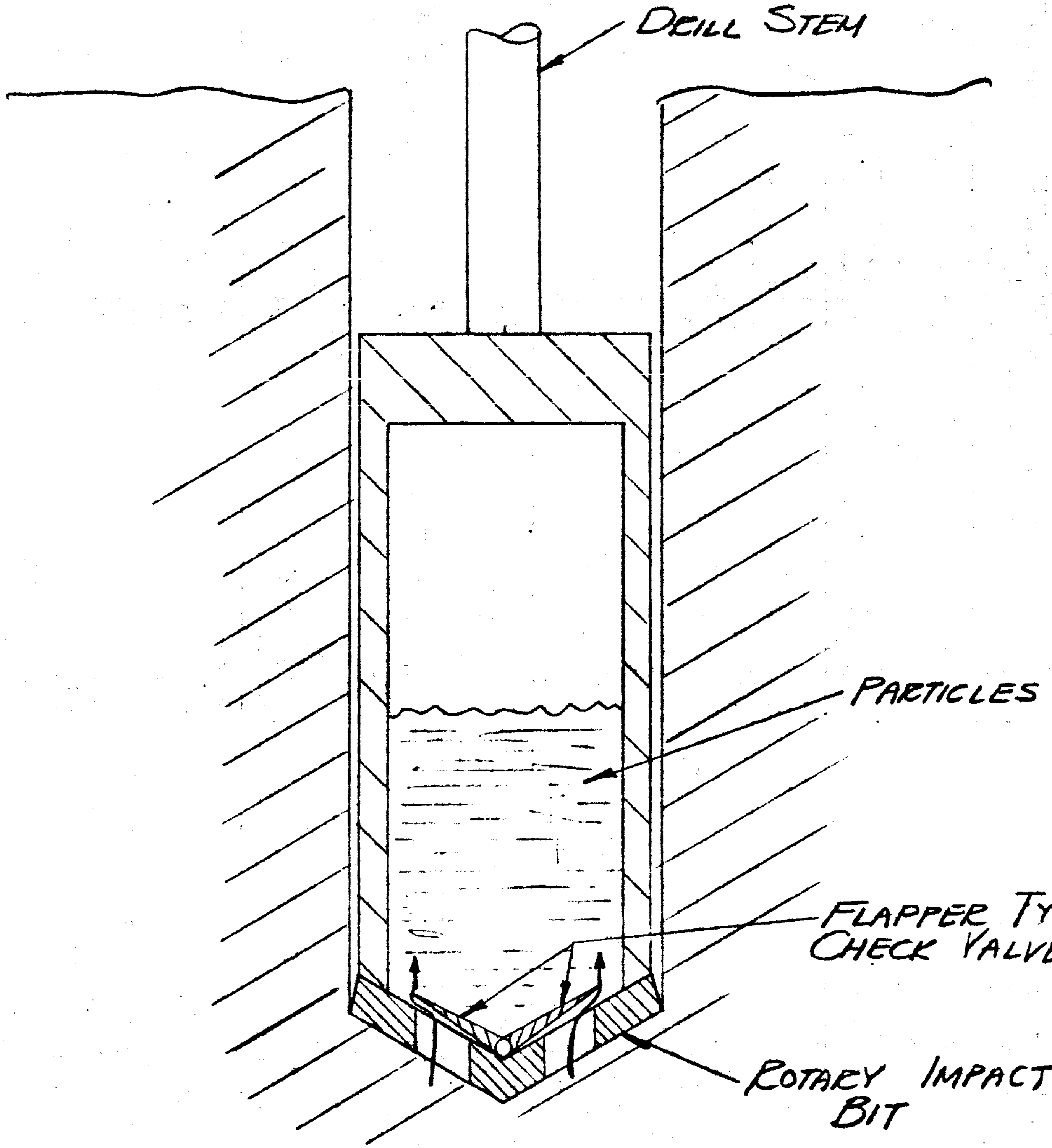

MECHANICAL CHECK VALVE CONCEPT

FIGURE A-10

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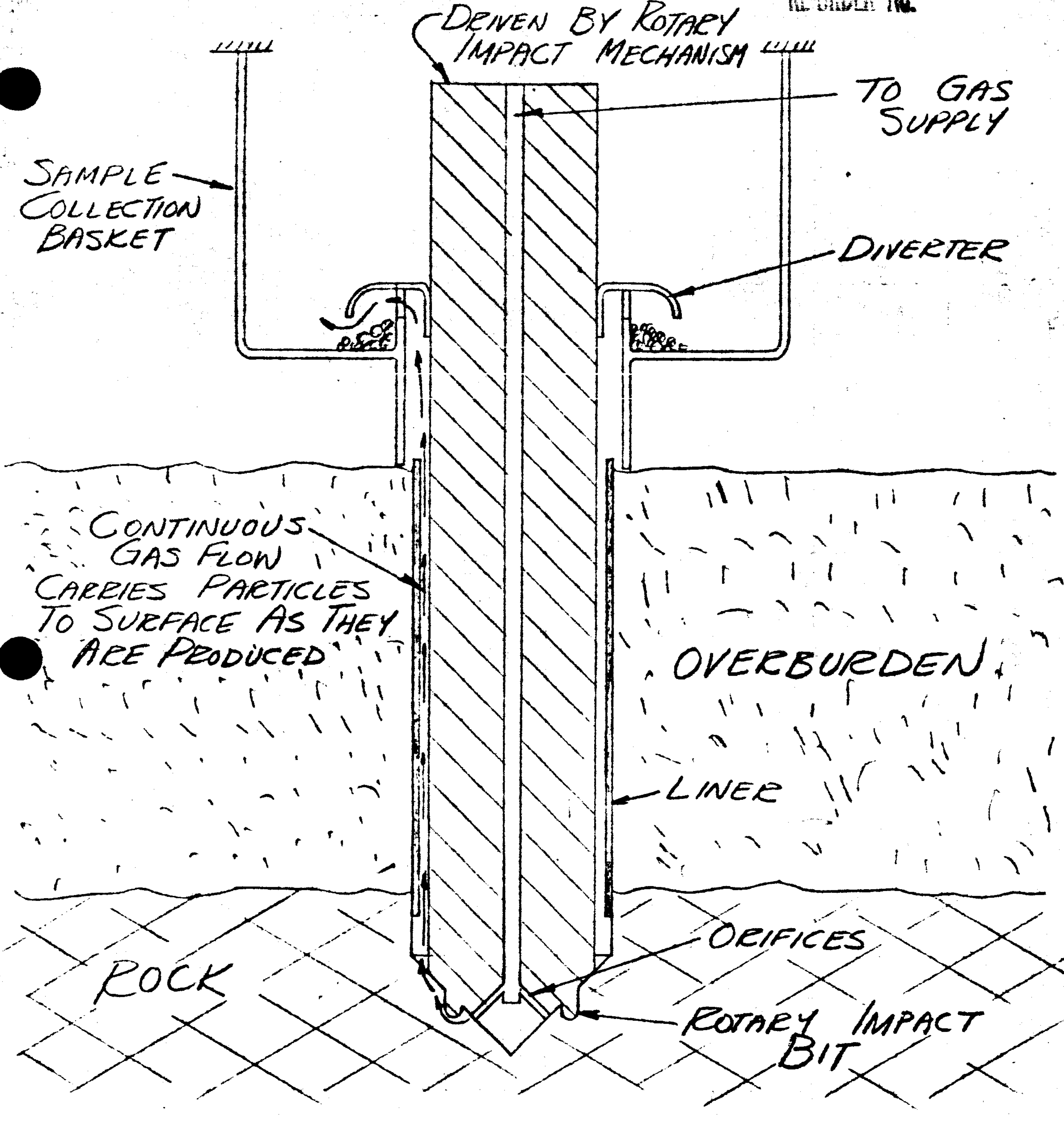

CONTINUOUS GAS TRANSPORT CONCEPT

FIGURE A-11

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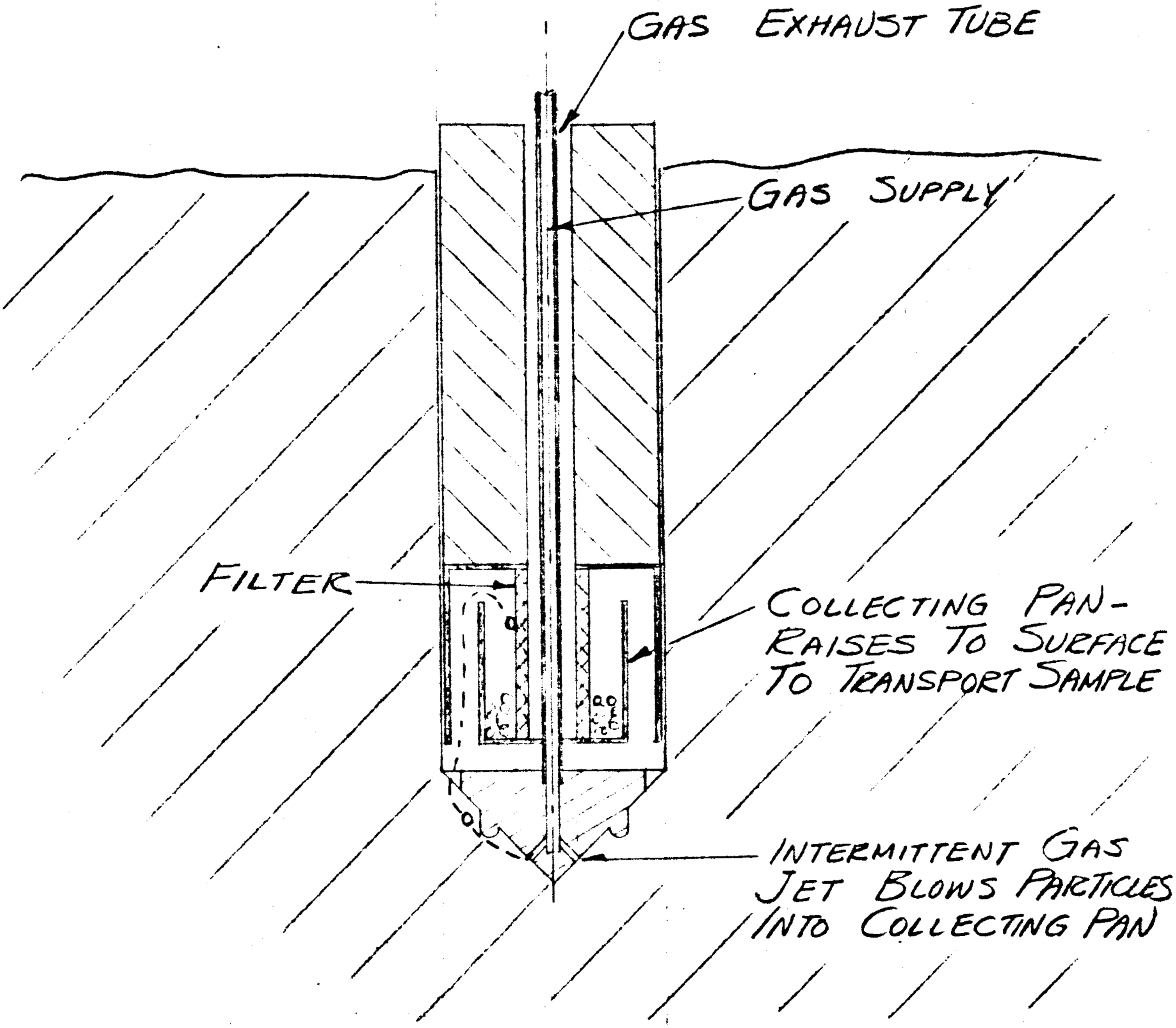

COMBINATION GAS AND MECHANICAL
TRANSPORT CONCEPT
FIGURE A-12

FMA
WALTHAM, MASS.
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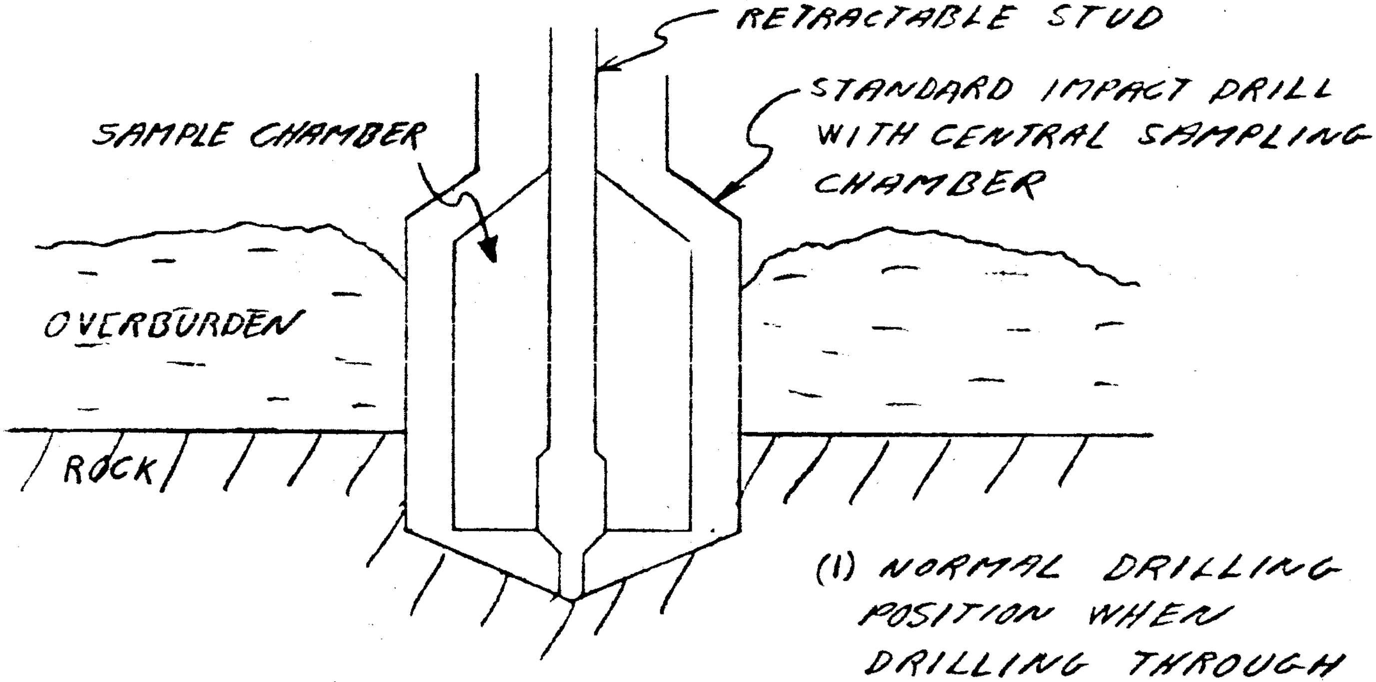
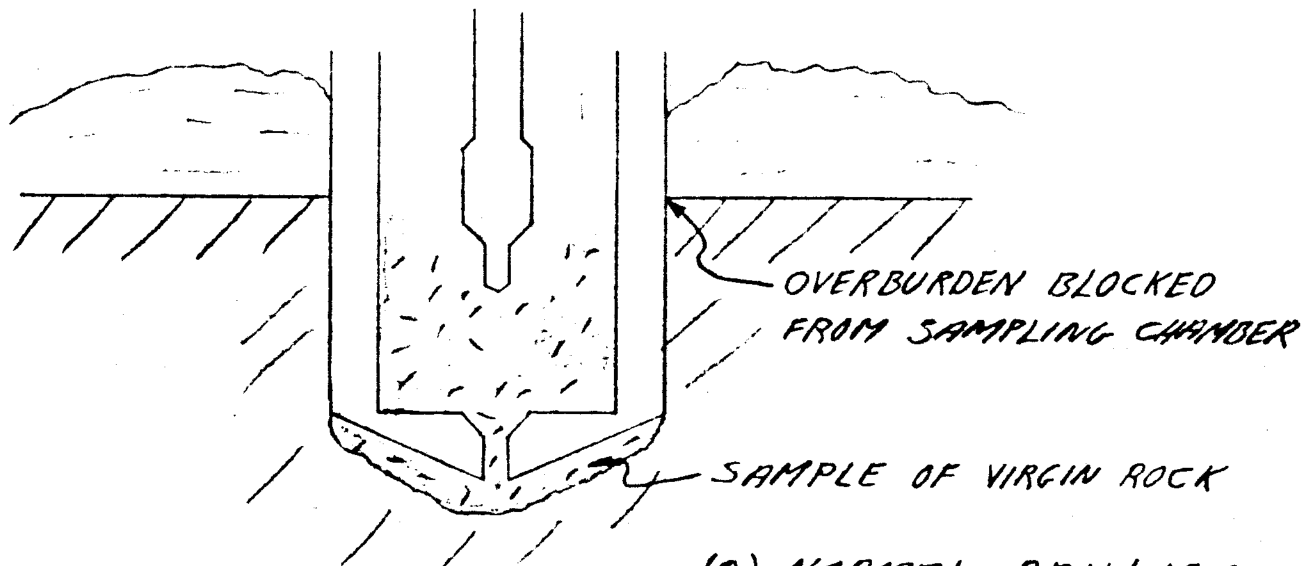
DEVICE TO PASS THROUGH OVERBURDEN AND ACQUIRE ROCK SAMPLE

7/2/65 P.V.



(1) NORMAL DRILLING POSITION WHEN DRILLING THROUGH OVERBURDEN



(2) NORMAL DRILLING POSITION (STUD RETRACTED) WHEN OBTAINING ROCK SAMPLE

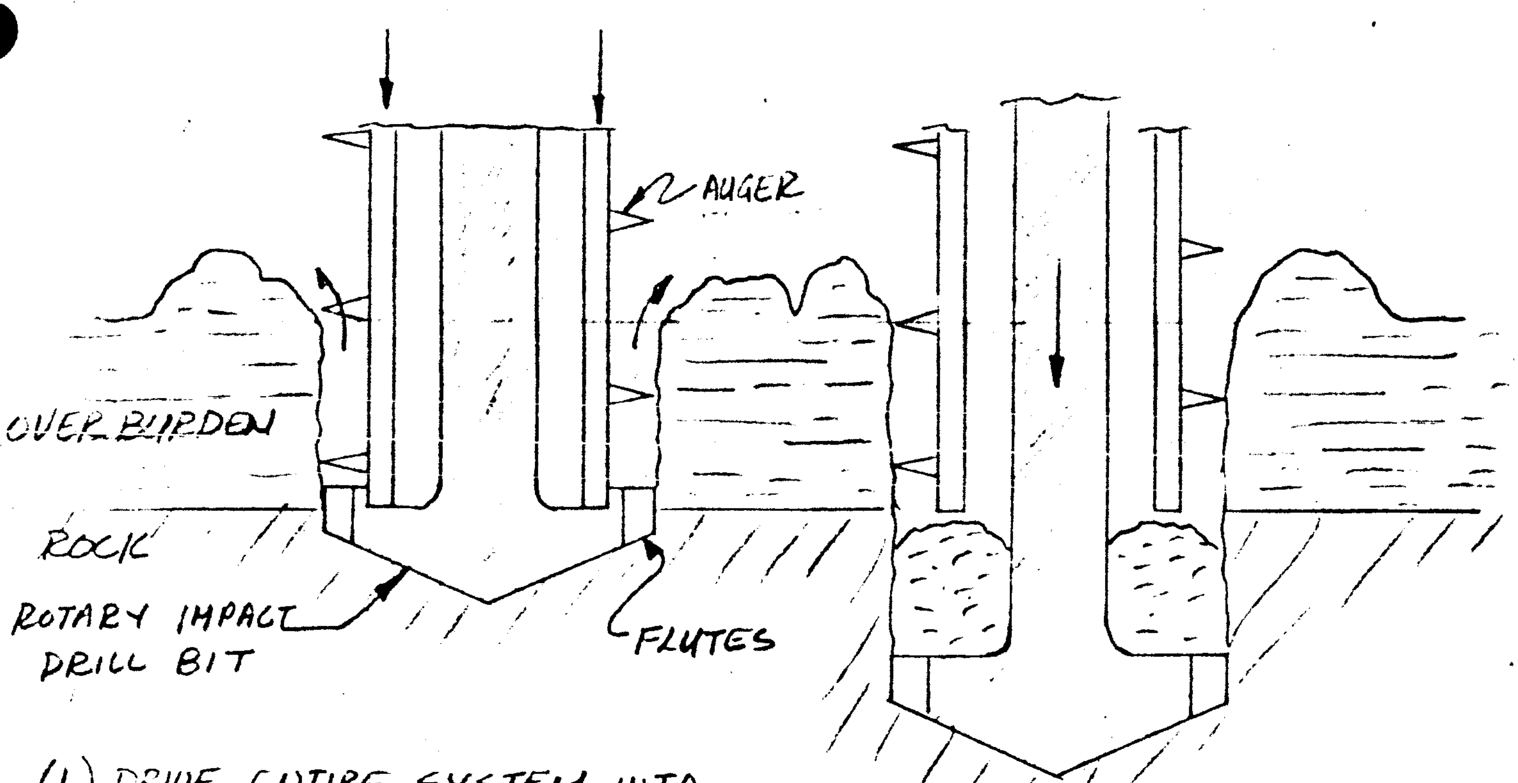
(3) DRILL ASSEMBLY IS RETRACTED AFTER SAMPLE IS OBTAINED

FIGURE A-13

RE ORDER NO. 65-757

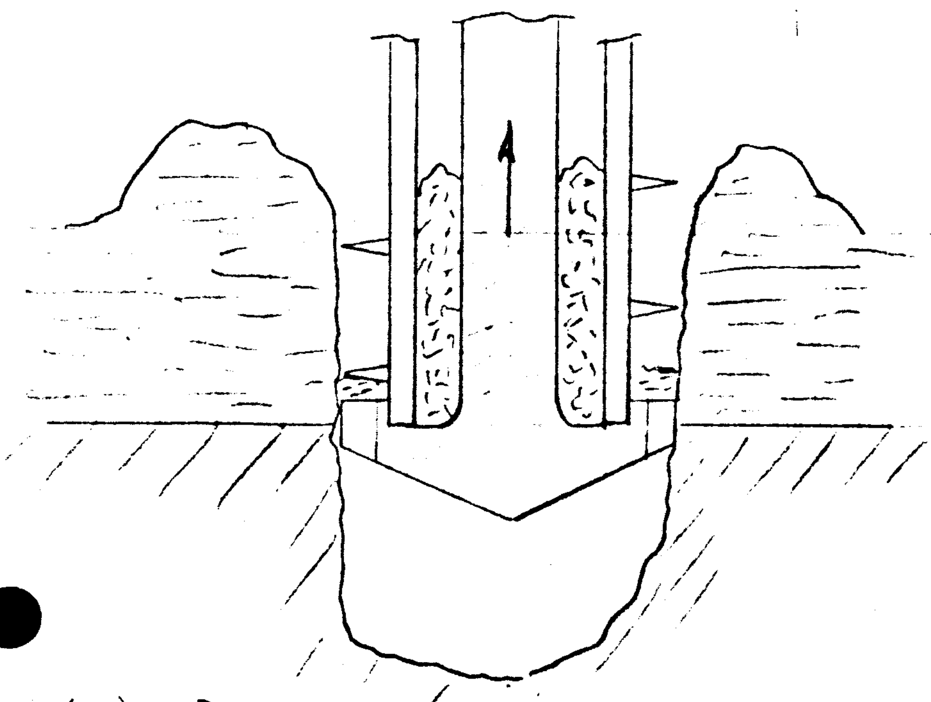
DM 6/22/65

ENVELOPING TRANSPORT DEVICE



(1) DRIVE ENTIRE SYSTEM INTO SURFACE. AUGER THROWS OVERBURDEN CLEAR OF MOVING COMPONENTS.

(2) HOLDING AUGER STILL, DRIVE DRILL ASSEMBLY INTO SUBLAYER. AUGER TUBE ACTS AS LINER



(A) RETRACT ENTIRE ASSEMBLY TO SURFACE.

(3) RETRACT DRILL ASSEMBLY FORCING ROCK CHIPS INTO AUGER TUBE.

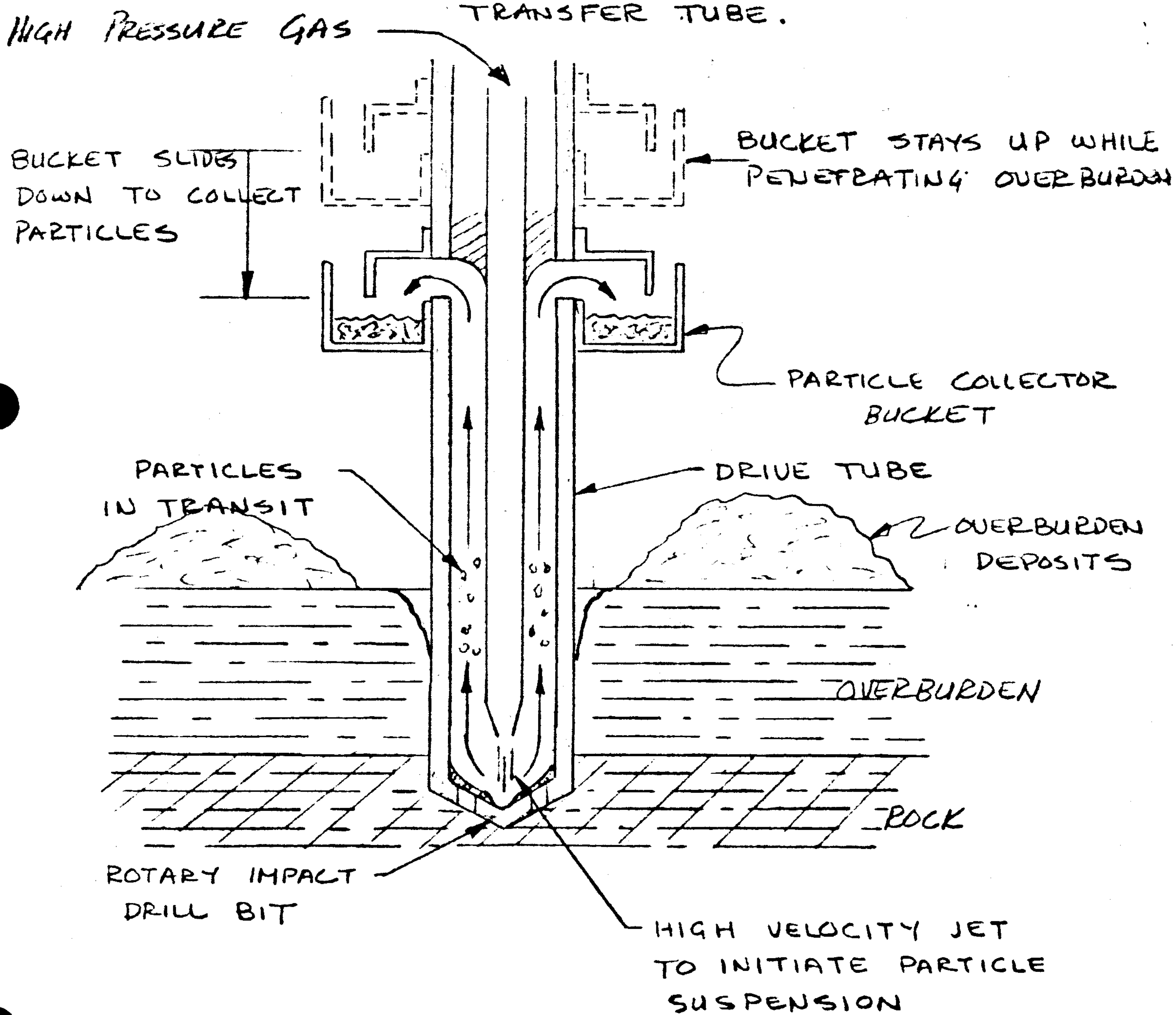
FIGURE A-14

DRM 6/21/65

H-6529 GEOLOGICAL SAMPLE ACQUISITION

PULSED GAS JET ACQUISITION DEVICE

OPERATION: (1) DRILL TUBE IS DRIVEN INTO LUNAR SUBSTANCE AS GAS IS INJECTED.
(2) PARTICLES ARE SWEPT UP BY HIGH VELOCITY GAS AND CARRIED UP TRANSFER TUBE.



COMMENTS: (1) CRITICAL PARTICAL SIZE MAY LIMIT THE SYSTEM CAPABILITIES.
(2) GAS SUPPLY MAY BE EXCESSIVE.

FIGURE A-15

RE ORDER No. 65-75-?

Mengin 6/29/65

CONTINUOUS GAS TRANSPORT WITH EXTERNAL VALVING

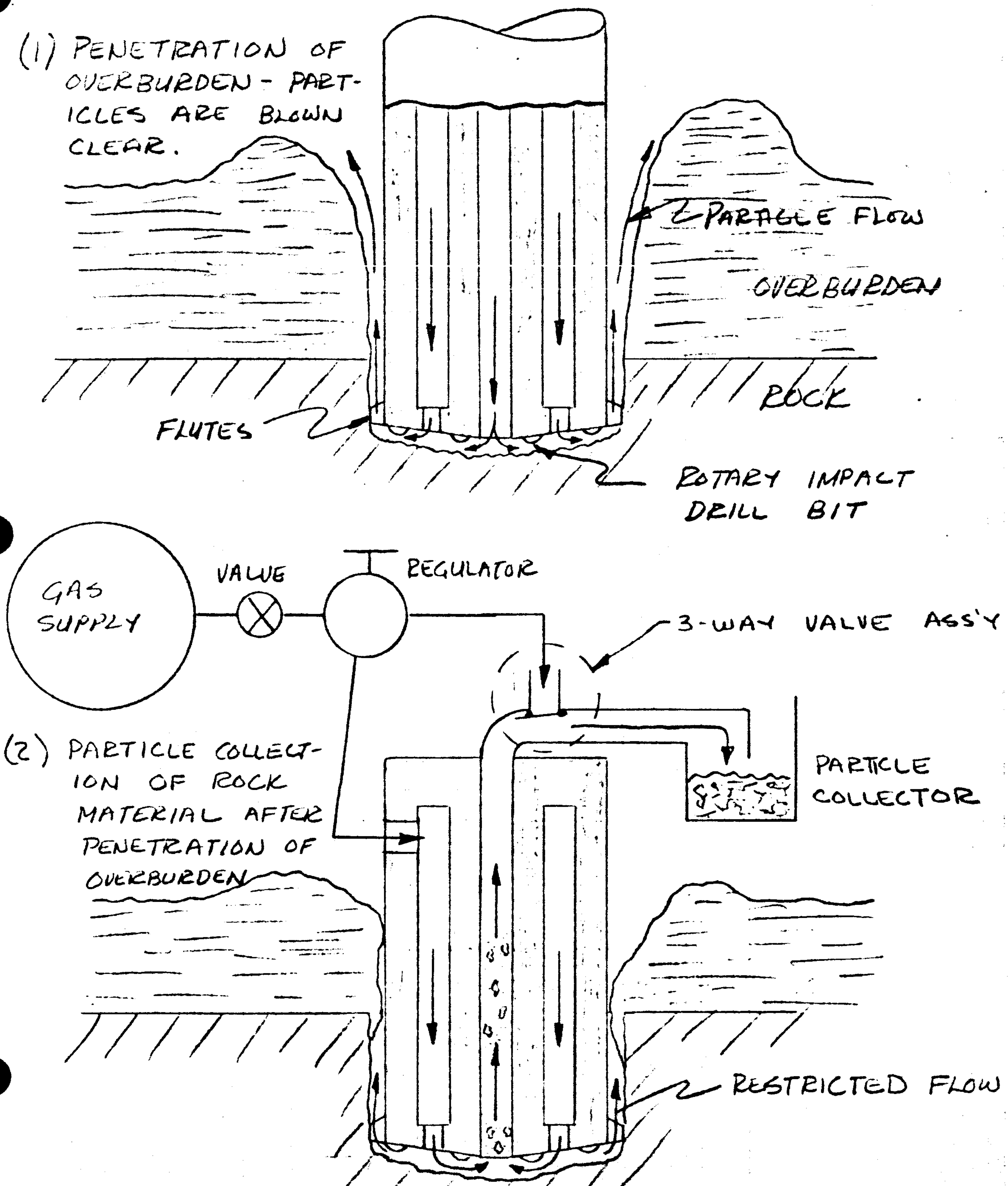


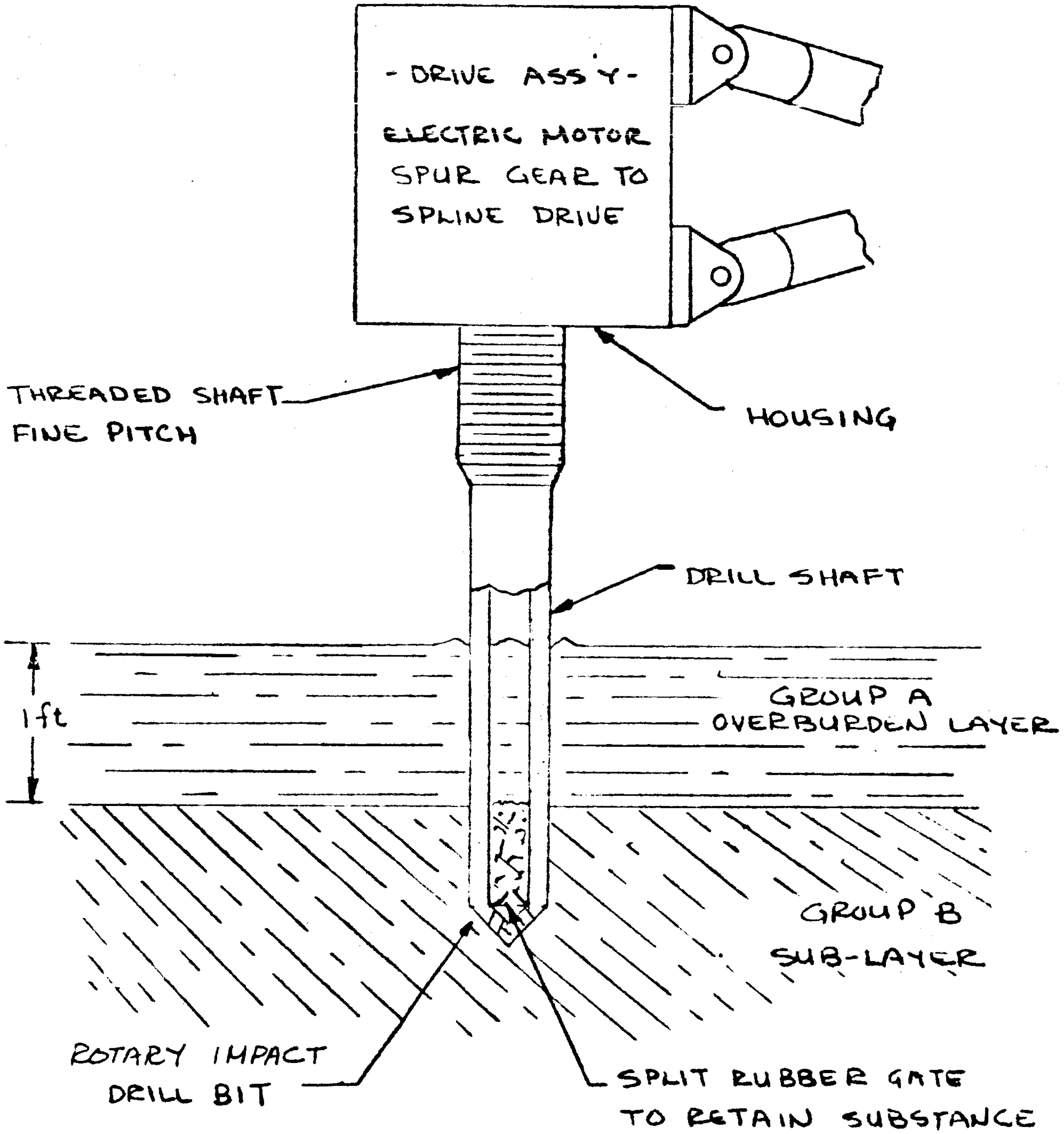
FIGURE A-16

No. 65-257

DRM 6/21/65

H-6529 GEOLOGICAL SAMPLE ACQUISITION

OPERATION: (1.) POSITION DRIVE ASS'Y. (2) START MOTOR & DRIVE RETRIEVER THROUGH OVERBURDEN AND WELL INTO SUBLAYER. (3) REVERSE MOTOR AND RETRACT RETRIEVER. GATE WILL RETAIN SUBSTANCE.

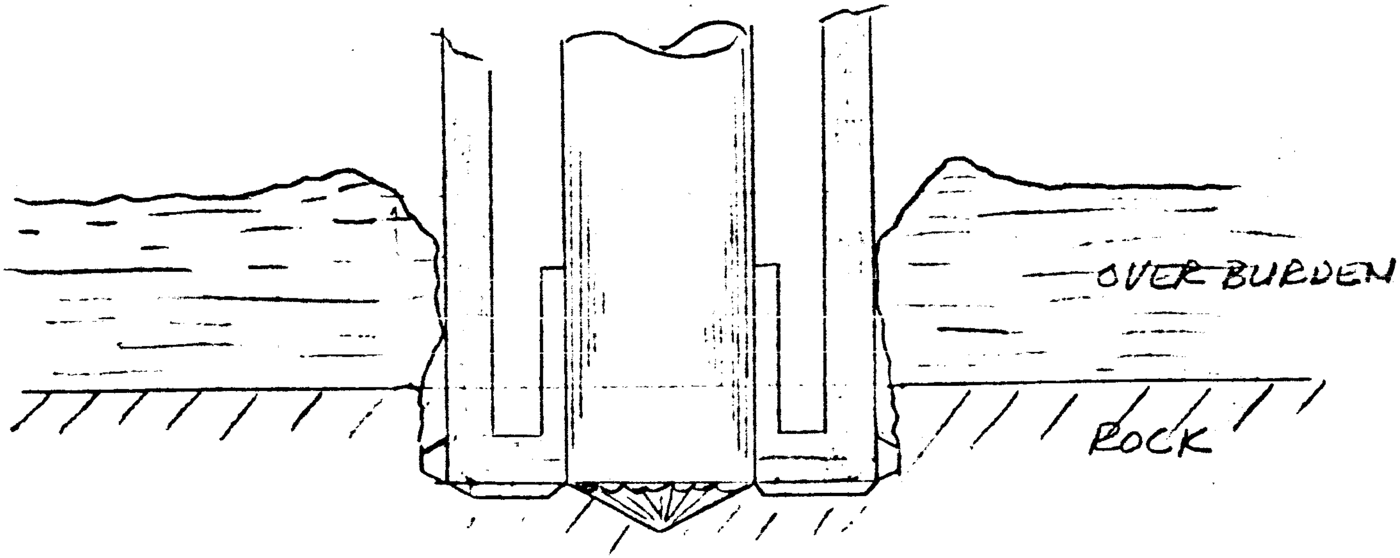


COMPACTING OVERBURDEN AND ROCK ACQUISITION DEVICE

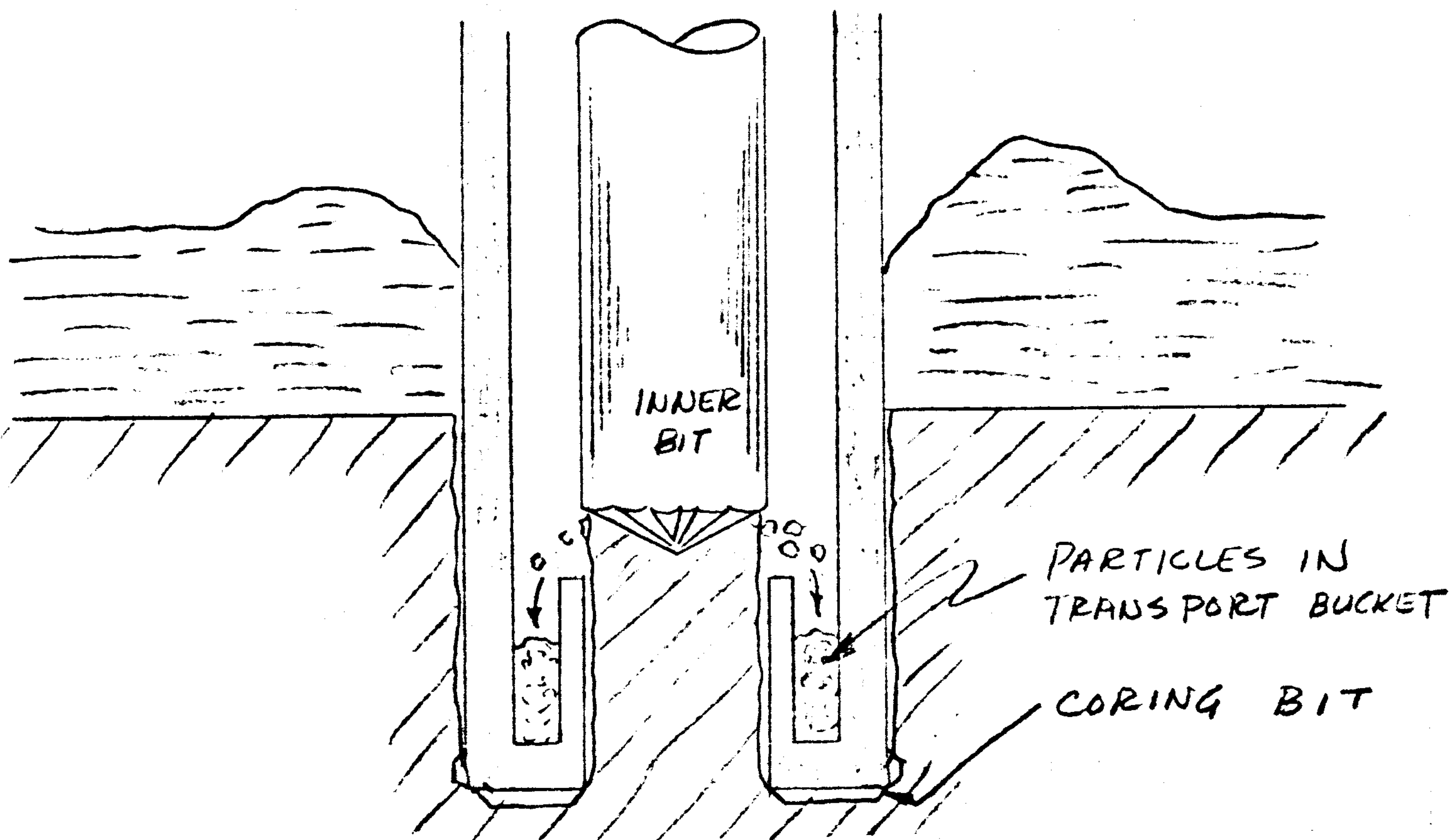
FIGURE A-17

RECORD No.

FRAGMENTING CORE GRAVITY ACQUISITION DEVICE



(1) SYSTEM IS DRIVEN INTO SURFACE (AS SHOWN) WELL INTO ROCK.



(2) CORING BIT IS ADVANCED, ALONE, UNTIL CORE CLEARS BUCKET SIDES. THEN, BOTH DRILLS ARE ADVANCED, CHIPPING PARTICES INTO BUCKET.

FIGURE A-18 A.1.31

6/23/65

CONTINUOUS GAS TRANSPORT WITH MECHANICAL VALVING

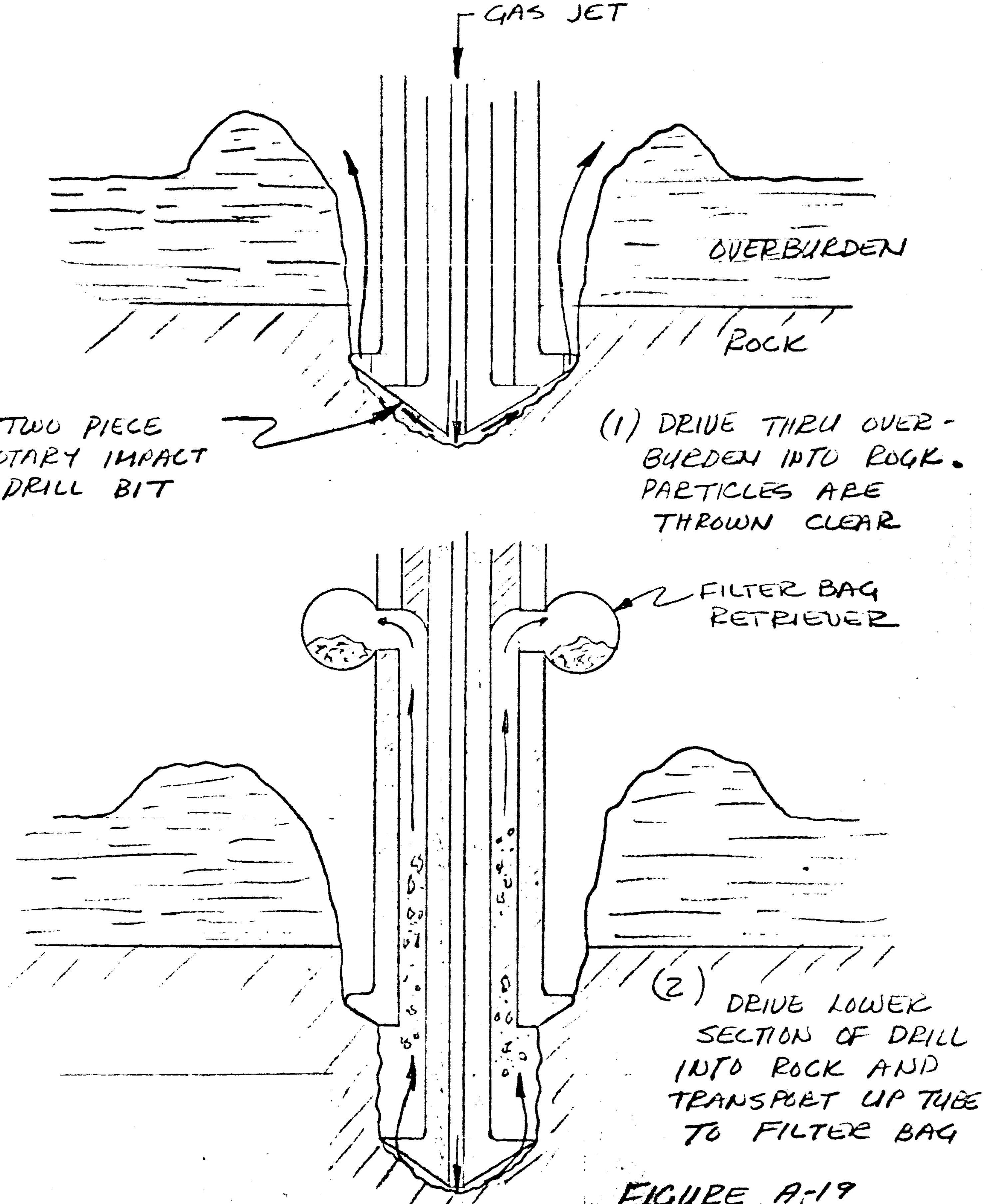


FIGURE A-19

ORDER No.

MECHANICAL VALVE BATCH COLLECTOR 7/2/65 P.V.

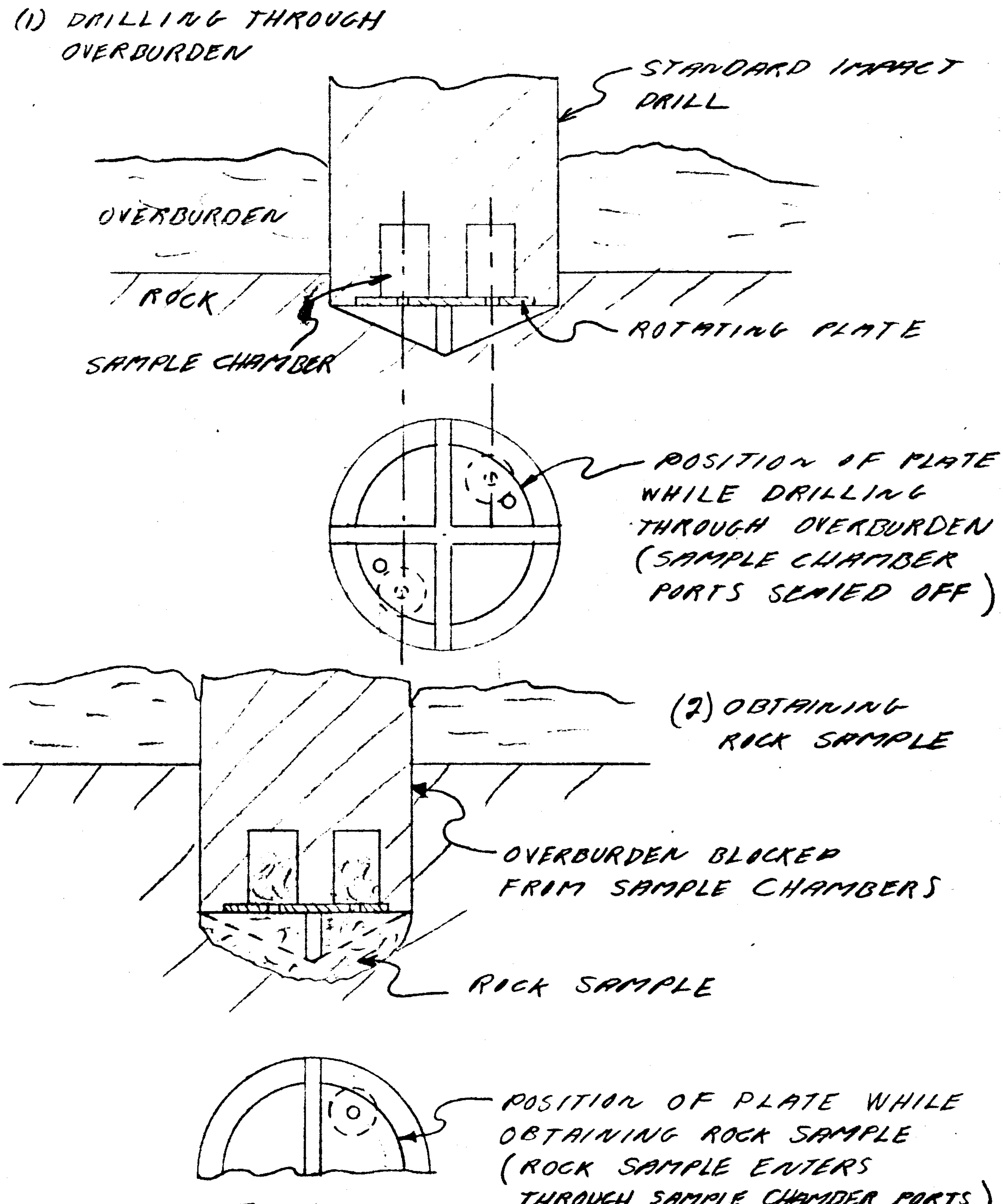
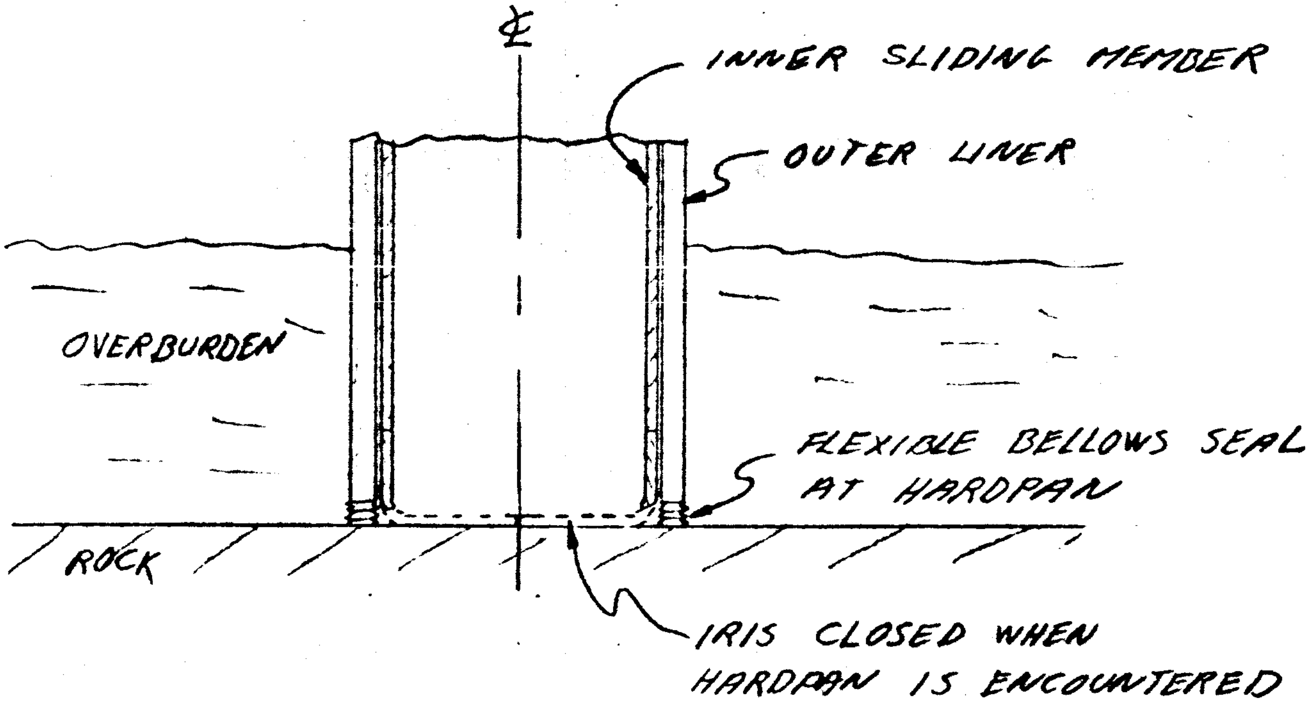


FIGURE A-20

7/2/65



WHEN HARDPAN IS REACHED, IRIS OR EQUIVALENT IS CLOSED AT THE BOTTOM OF THE INNER TUBE, SLIDING INNER MEMBER IS LIFTED (IT MAY BE DISCARDED OR SAVED - FOR SAMPLE RETRIEVAL AFTER DRILLING PHASE)

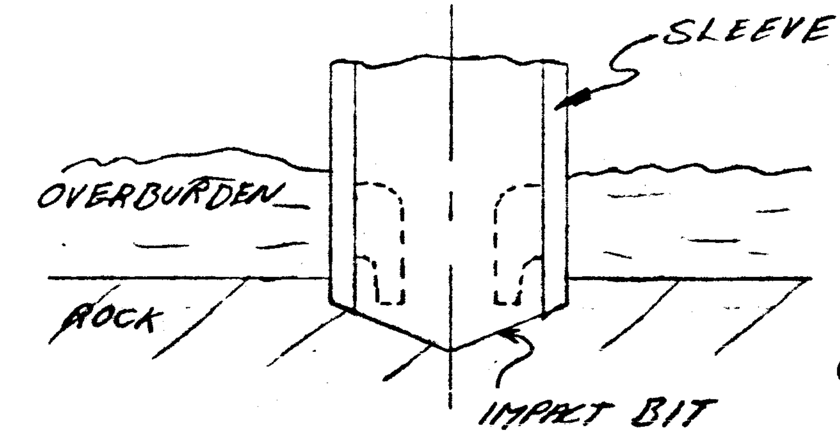
DRILLING MEANS NOT INCLUDED IN THIS CONCEPT.

<u>OVERBURDEN BATCH COLLECTOR</u>

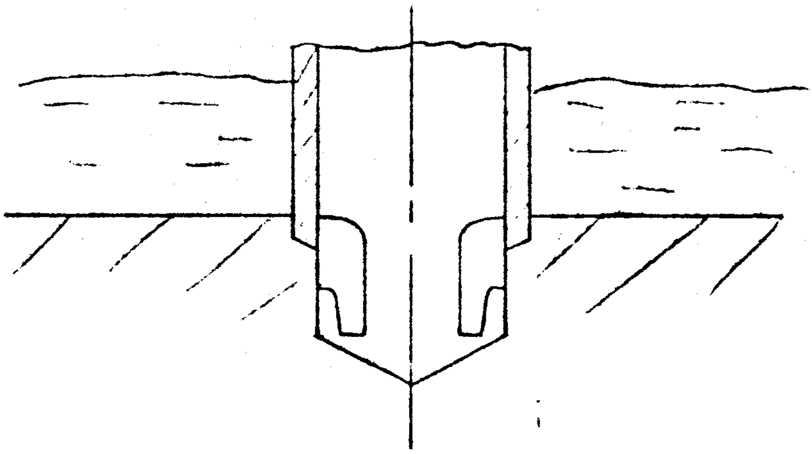
<u>FIGURE A-21</u>

GRAVITY REAMING AQUISITION DEVICE

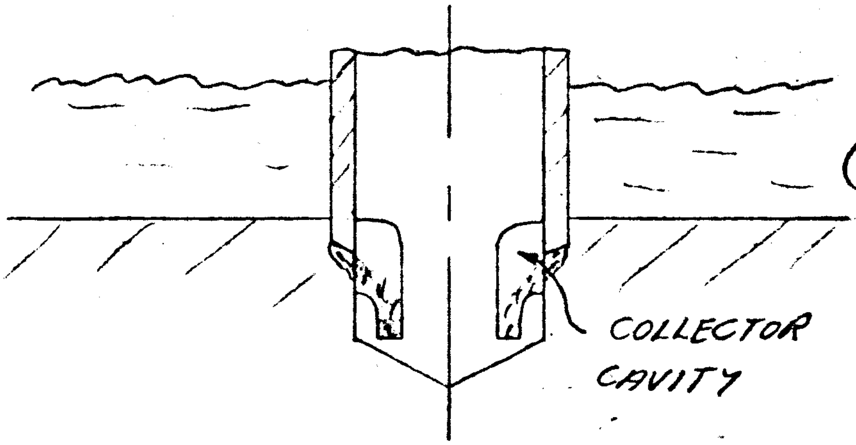
7/2/65
R.V.



(1) GO THROUGH OVERBURDEN (COMPACTING) AND PENETRATE HARDPAN SLIGHTLY. (BOTH PARTS IMPACTING TOGETHER)



(2) HOLD SLEEVE AND CONTINUE DRILLING ROCK WITH IMPACT BIT



(3) CHIPS FALL INTO COLLECTOR CAVITY. AS SLEEVE IMPACTS AND ADVANCES. WHEN CAVITY IS BLOCKED BY SLEEVE COMPLETE UNIT IS RETRACTED.

FIGURE A-22

APPENDIX A.2

PROGRESS REPORT #3

FOSTER-MILLER ASSOCIATES, INC. to
HUGHES TOOL COMPANY
17 AUGUST 1965

Description of Work Performed During This Period

1. Program Outline

During this reporting period the following work was performed to complete our program objectives:

a. Ten concepts (listed in Table IV of Progress Report No. 2) previously considered promising, were reviewed and modified.

b. These concepts were then classified and compared with those considered most promising recommended for development.

c. Conclusions based on the work accomplished by Foster-Miller Associates throughout this project were summarized.

The results of this effort are presented in the following sections.

2. Review and Modification of Promising Concepts

After receiving the results of the July 14, 1965 design review conducted at Jet Propulsion Laboratory, the remaining concepts were reviewed. Wherever possible, modifications were effected to correct concept weaknesses. Effort was concentrated on improving the following areas:

a. Sealing overburden out of the rock sampling region to minimize contamination.

b. Providing for overburden sampling in those concepts which previously lacked this feature.

c. Minimizing the possibility of sample loss through fissures by "closing" the flow path utilized in gas transport concepts.*

d. Laying out the "downhole" equipment required (for each concept) full scale to demonstrate feasibility in holes no larger than one inch diameter.

2.1 Description of the Modified Concepts

The modified versions of the retained concepts are shown schematically in Figures 1 through 9 of this report. For convenience they are assigned concept numbers FM-1 through FM-9 respectively.

The explanatory notes appearing on these figures, and the tabulation of task accomplishment methods appearing in the following subsection serve to describe each concept.

2.2 Classification of Concepts

Concepts FM-1 through FM-9 may be classified according to the method each employs to accomplish major mission tasks. These major tasks are defined as follows:

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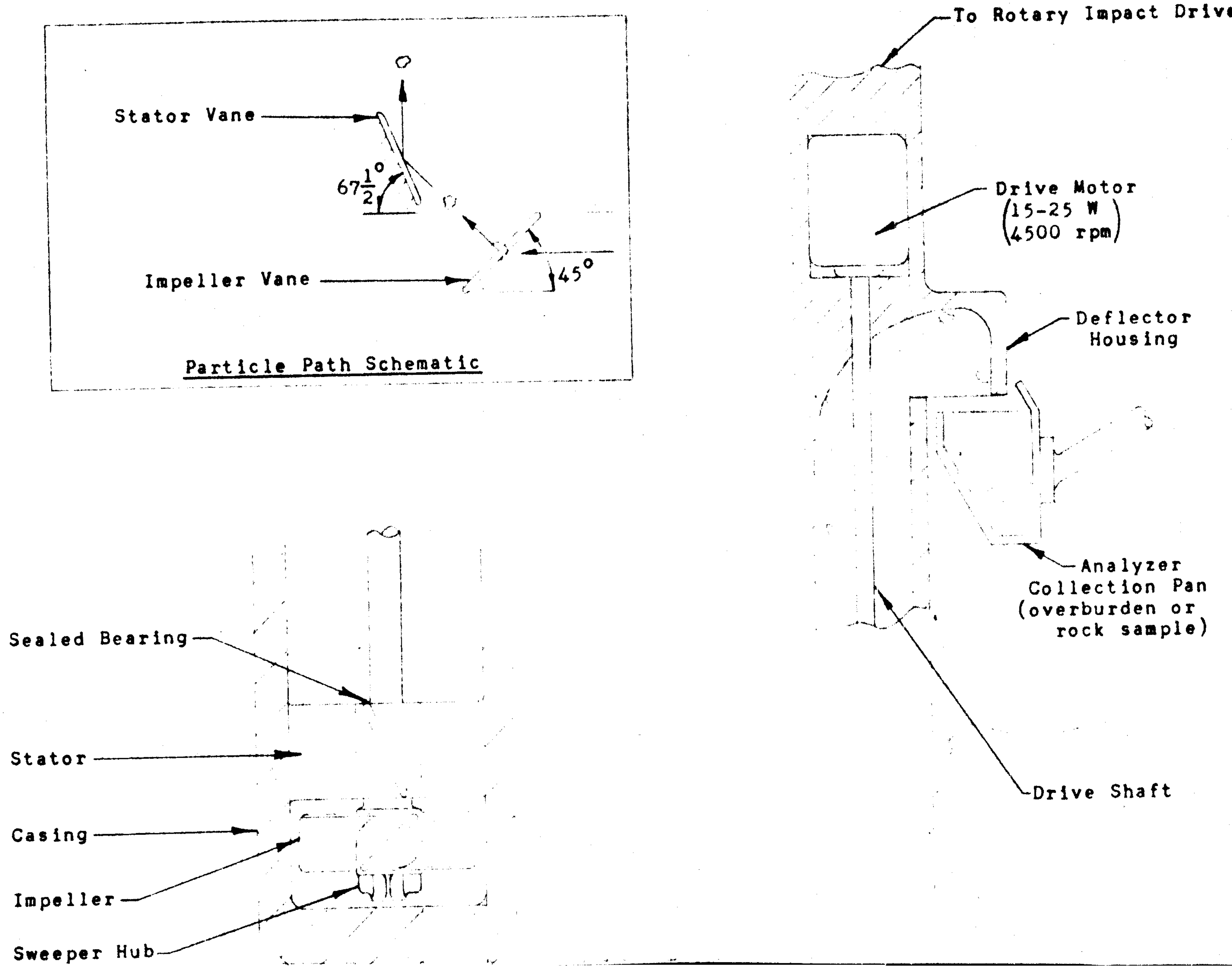
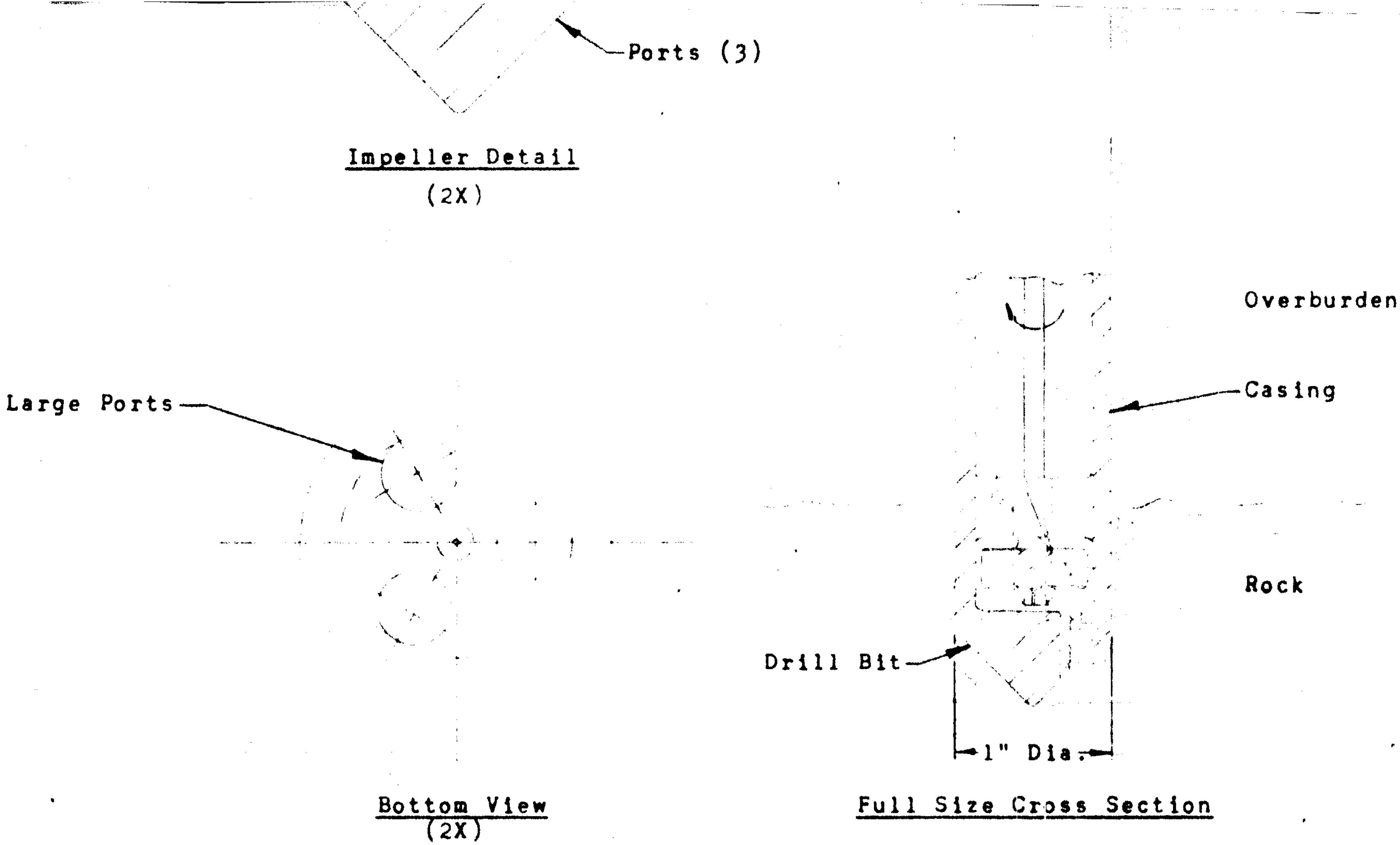
*This required that particle acquisition (as defined in Progress Report No. 2) be accomplished by means of "particle flow" induced by the impacting action of the drill, and represents an improvement only if the reliability of the particle flow process is greater than the probability of not encountering a fissure.

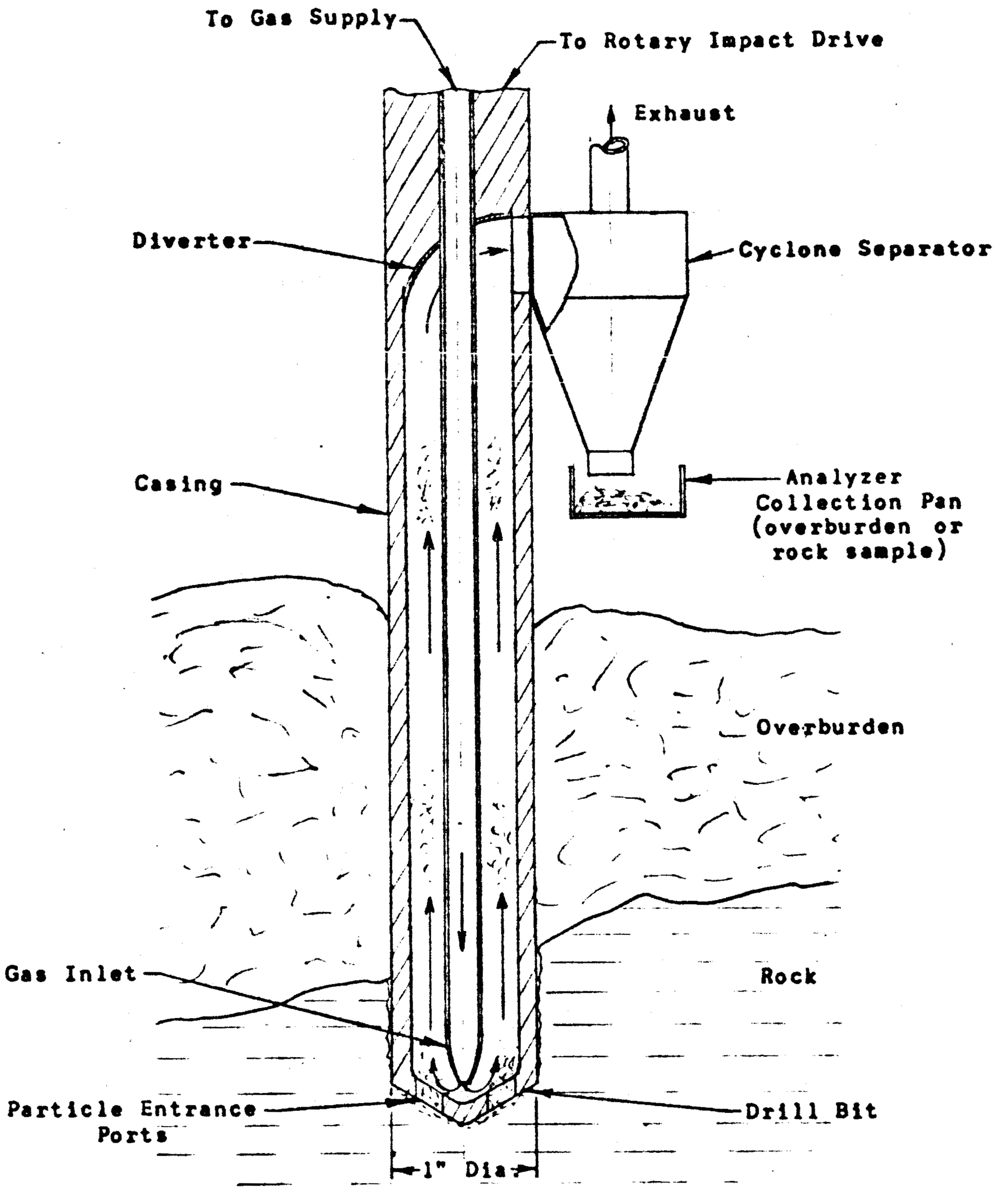

Stator Vane
$67\frac{1}{2}^{\circ}$
Impeller Vane
45°
Particle Path Schematic
Sealed Bearing
Stator
Casing
Impeller
Sweeper Hub
To Rotary Impact Drive
Drive Motor
(15-25 W
4500 rpm)
Deflector
Housing
Analyzer
Collection Pan
(overburden or
rock sample)
Drive Shaft

2



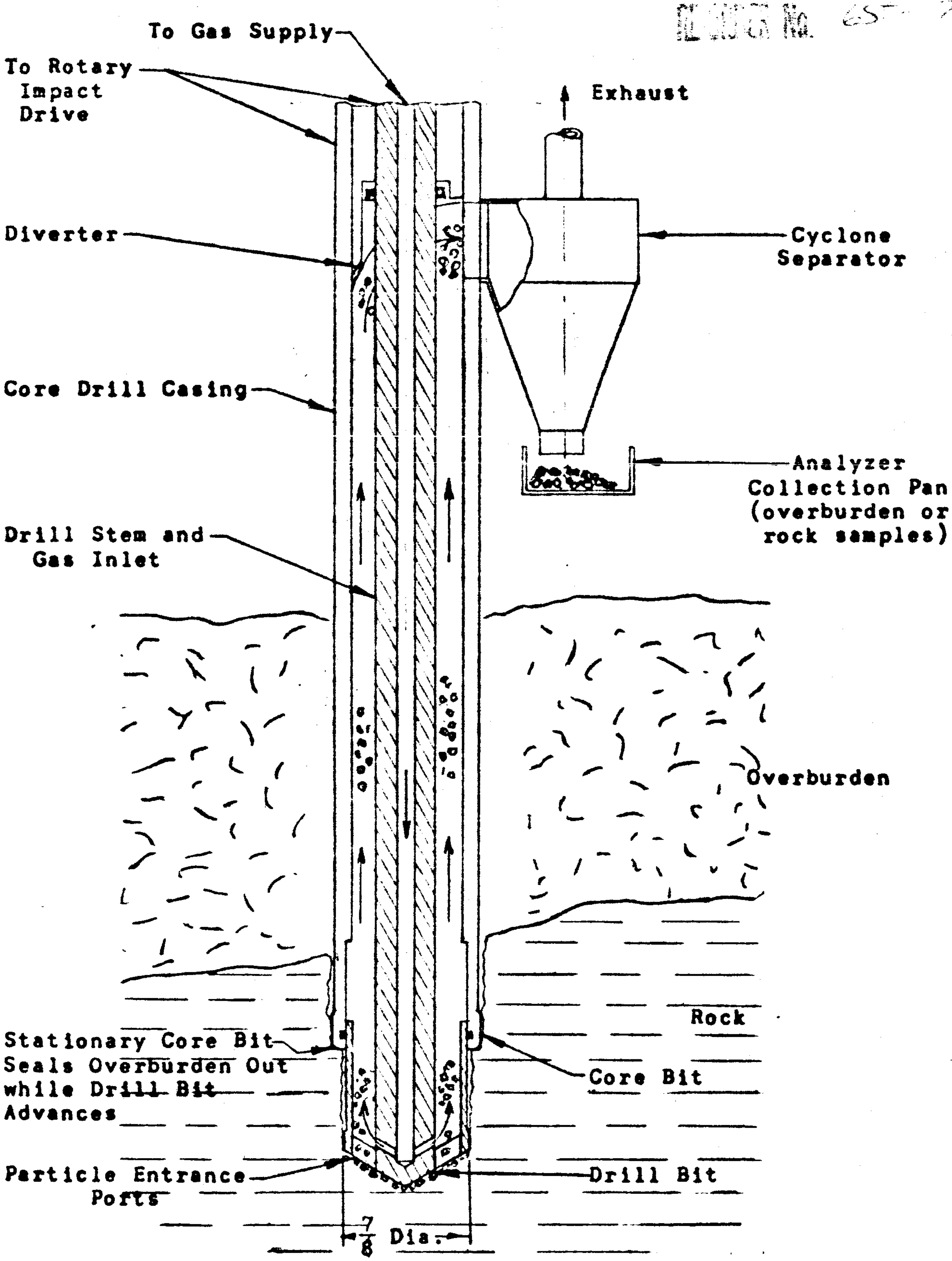
Continuous Impeller Concept (FM-1)

Figure 1



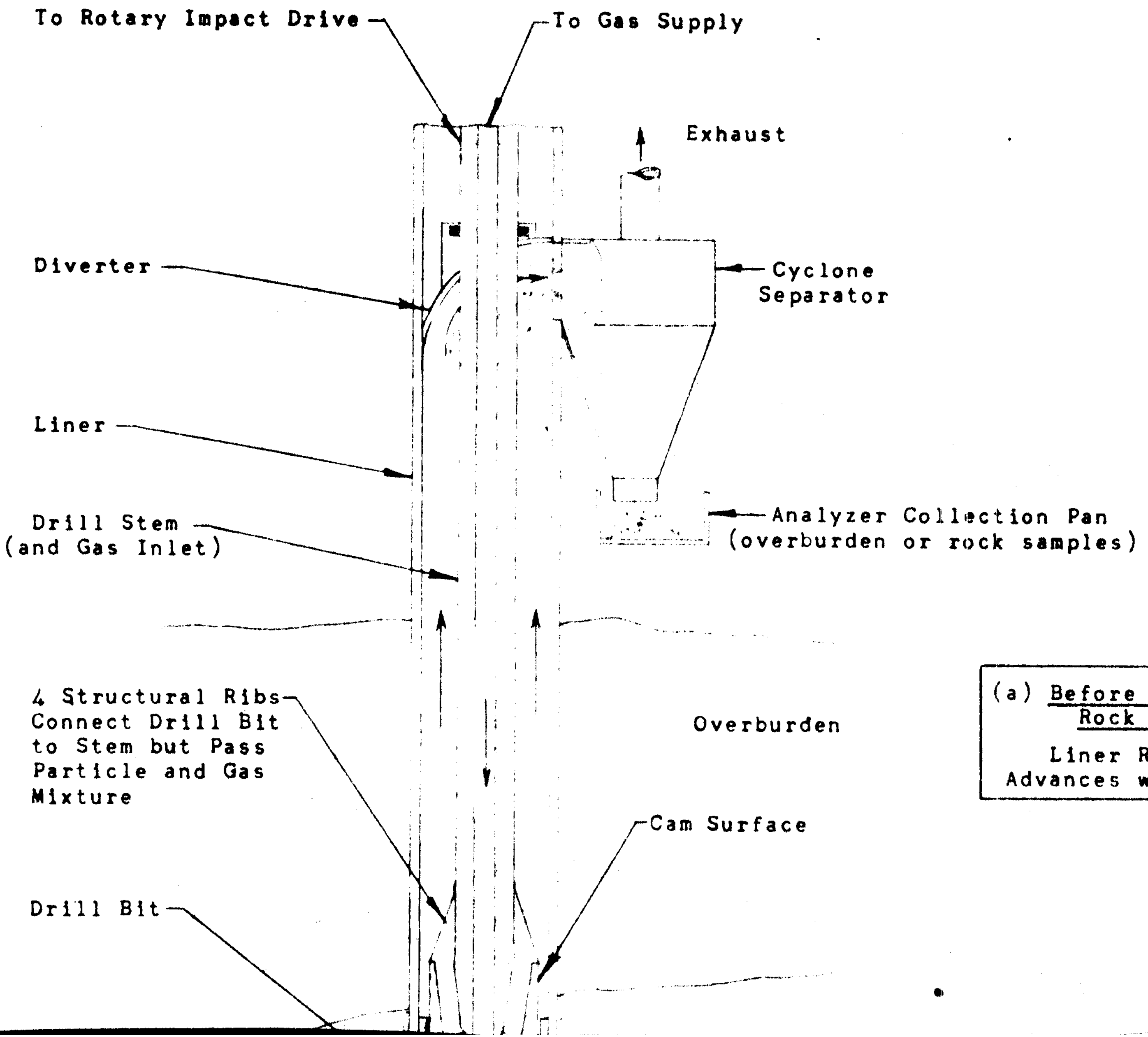
Continuous Gas Transport Concept (FM-2) without Overburden Seal

Figure 2



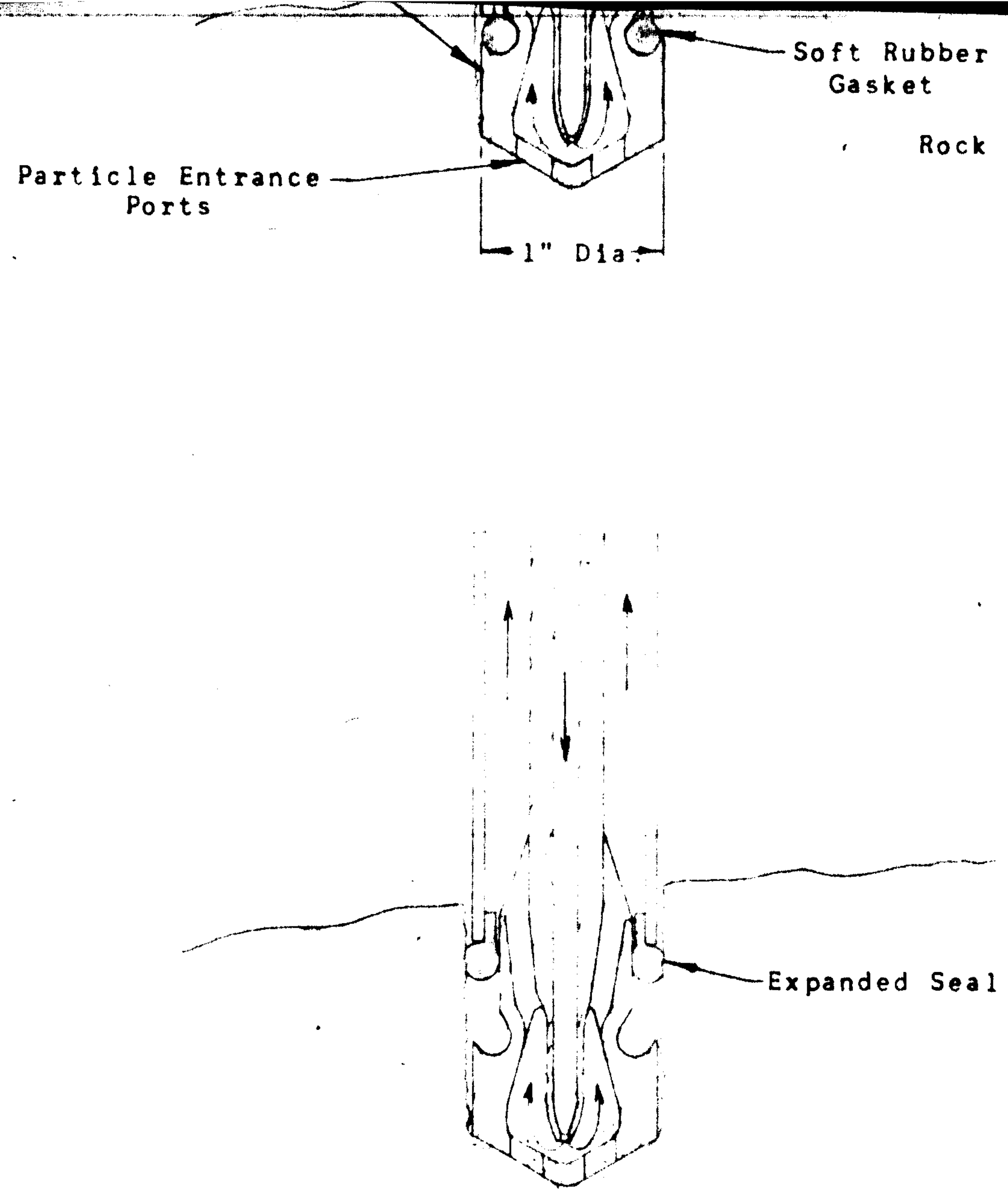
Continuous Gas Transport Concept (FM-3) with Core Drill Overburden Seal

Figure 3



(a) Before (and After) Rock Sampling

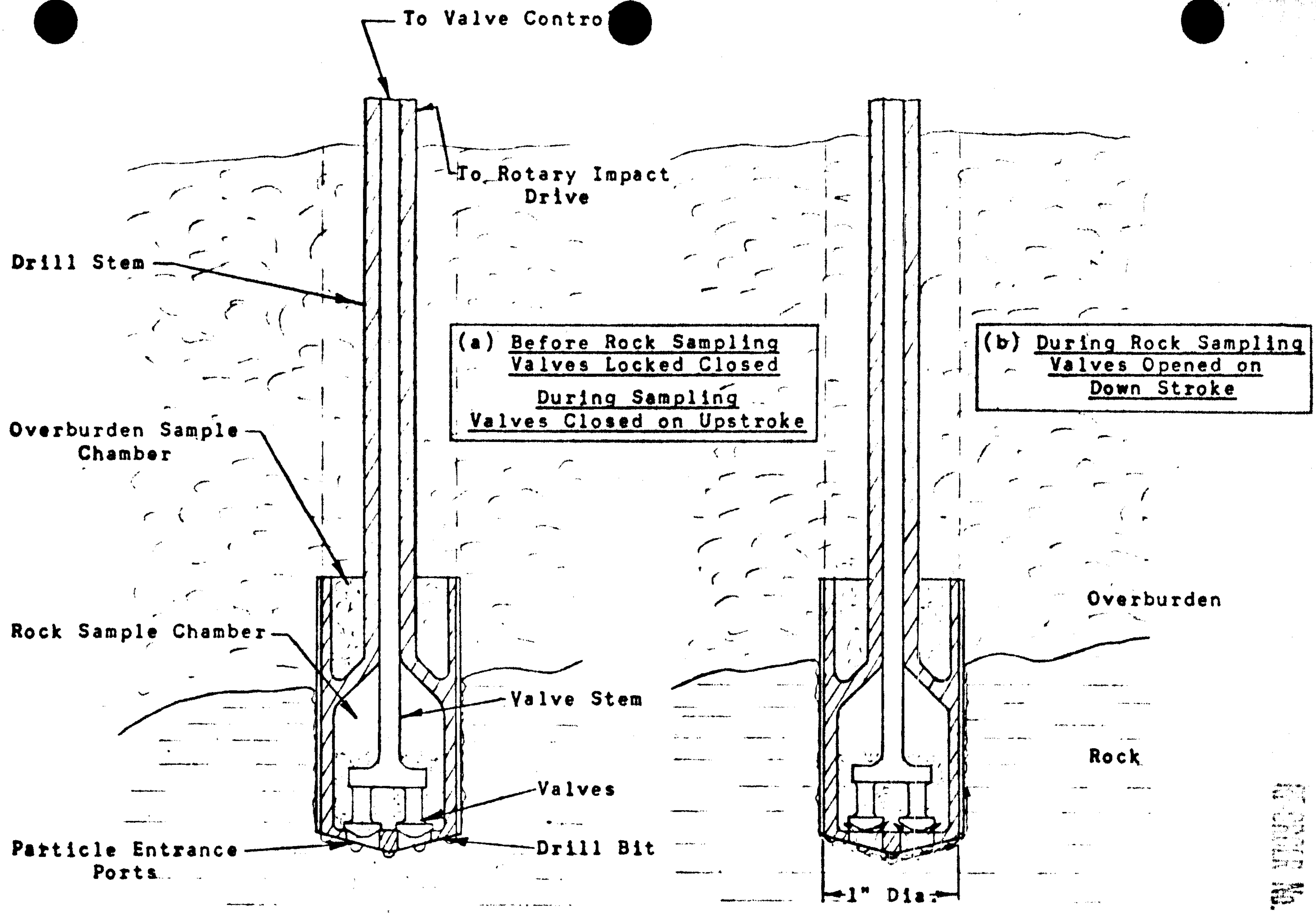
Liner Rotates and Advances with Drill Bit



(b) During Rock Sampling
Liner Stationary while
Drill Bit Advances

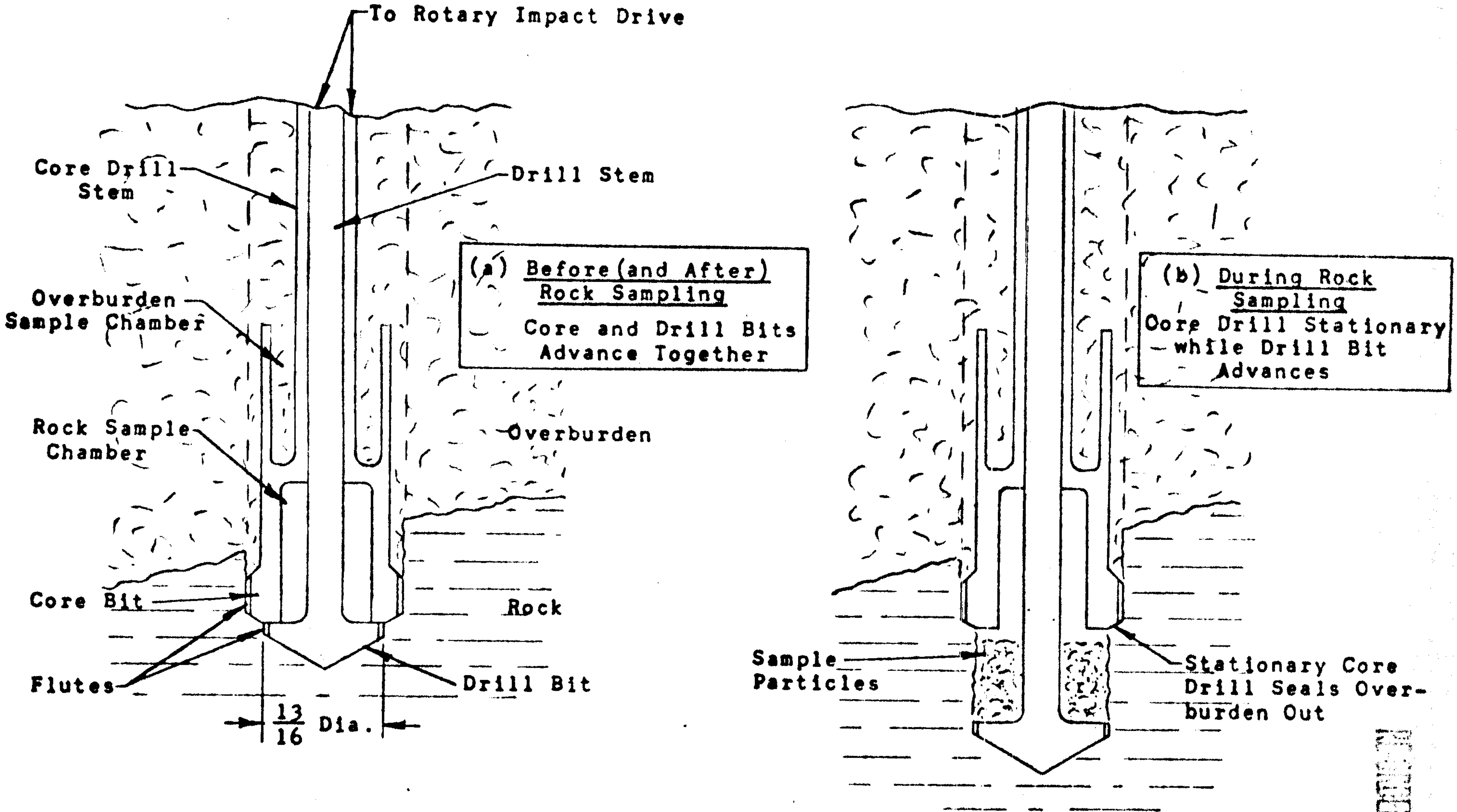
Continuous Gas Transport Concept (FM-4) with Expanding Overburden Seal

Figure 4



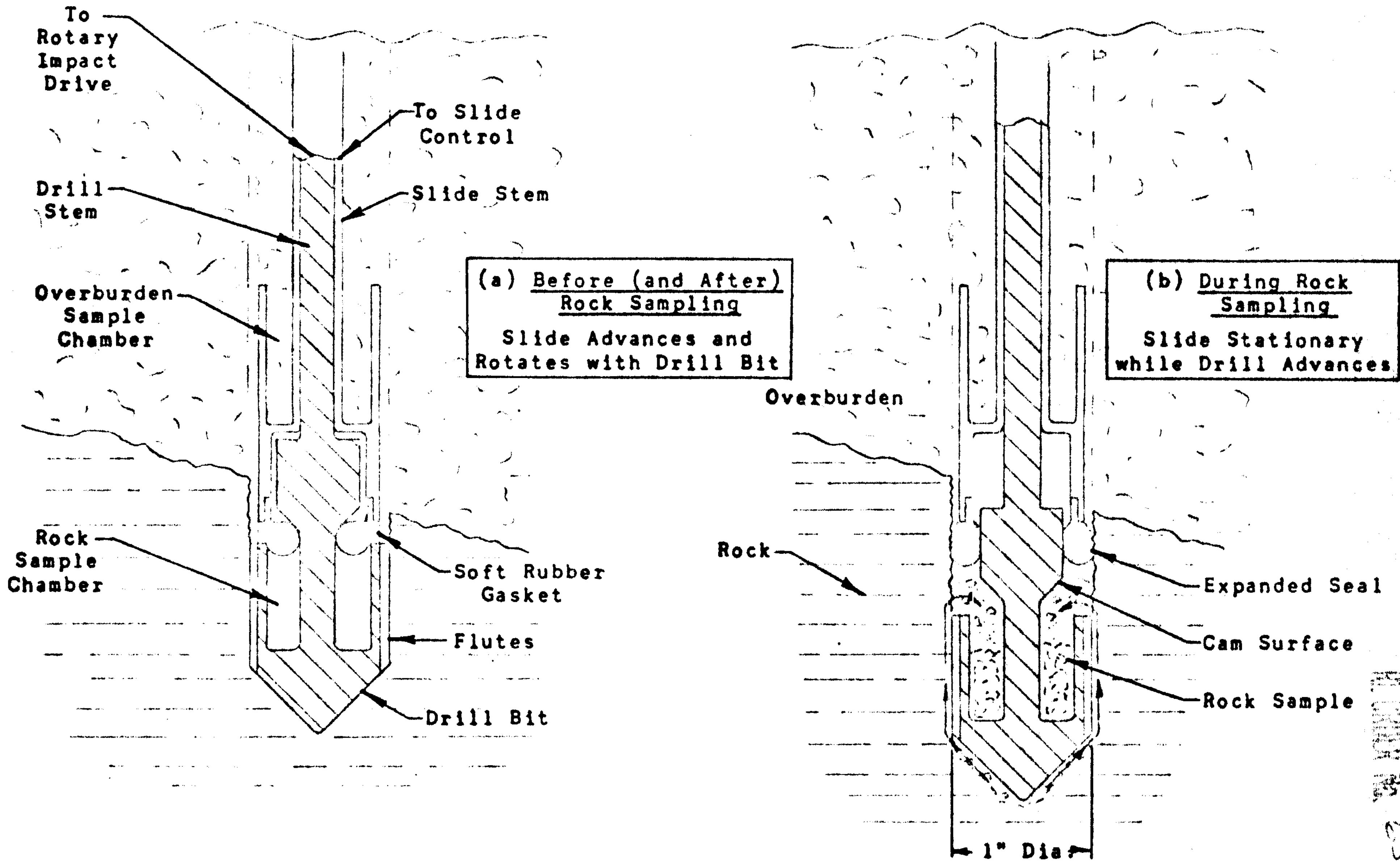
Batch Collector Concept (FM-5) with Externally Operated Valves

Figure 5



Batch Collector Concept (FM-6) with Core Bit Overburden Seal

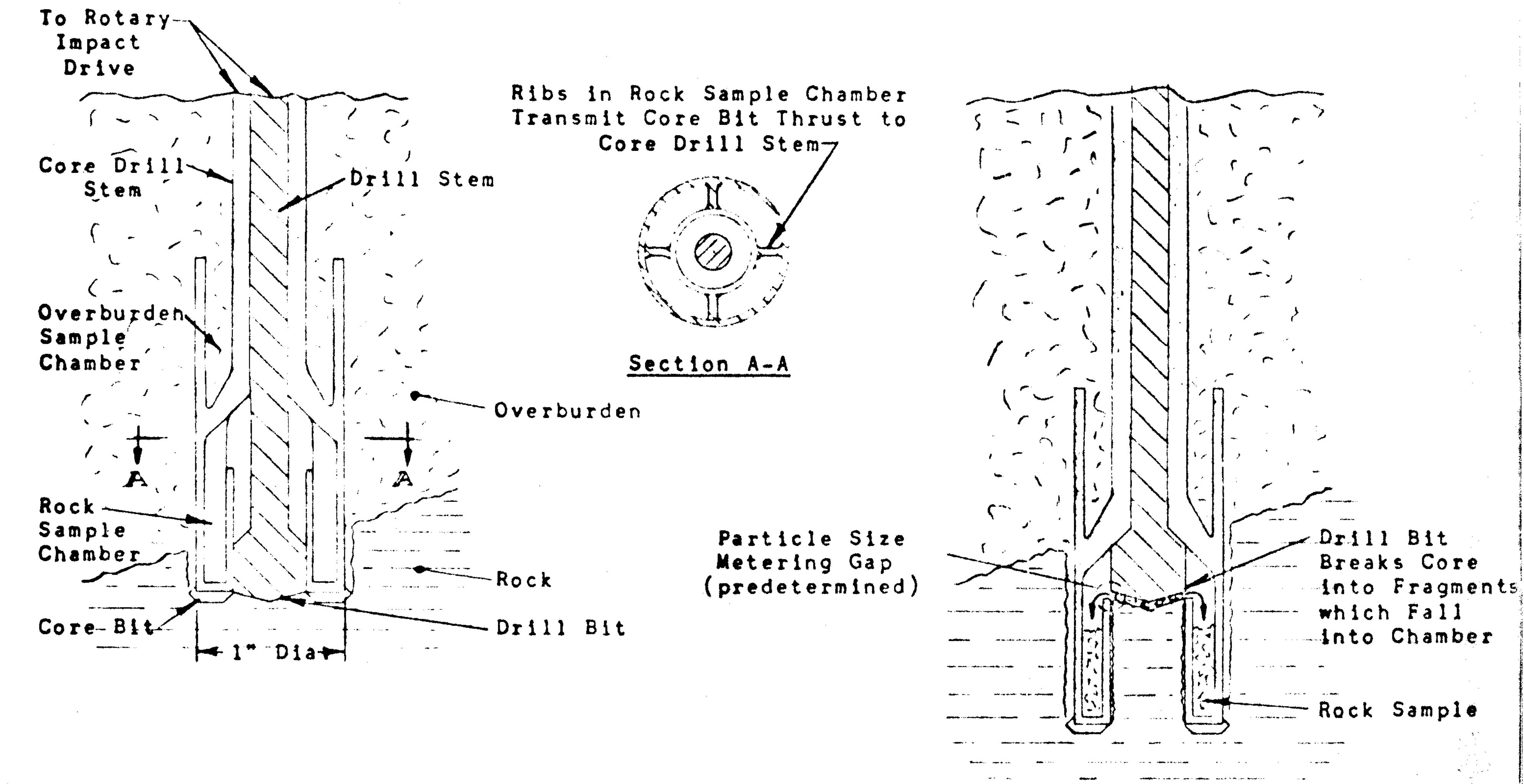
Figure 6



Batch Collector Concept (FM-7) with Expanding Overburden Seal

Figure 7

HD ORDER No. 65-757



(a) Before and After Rock Sampling

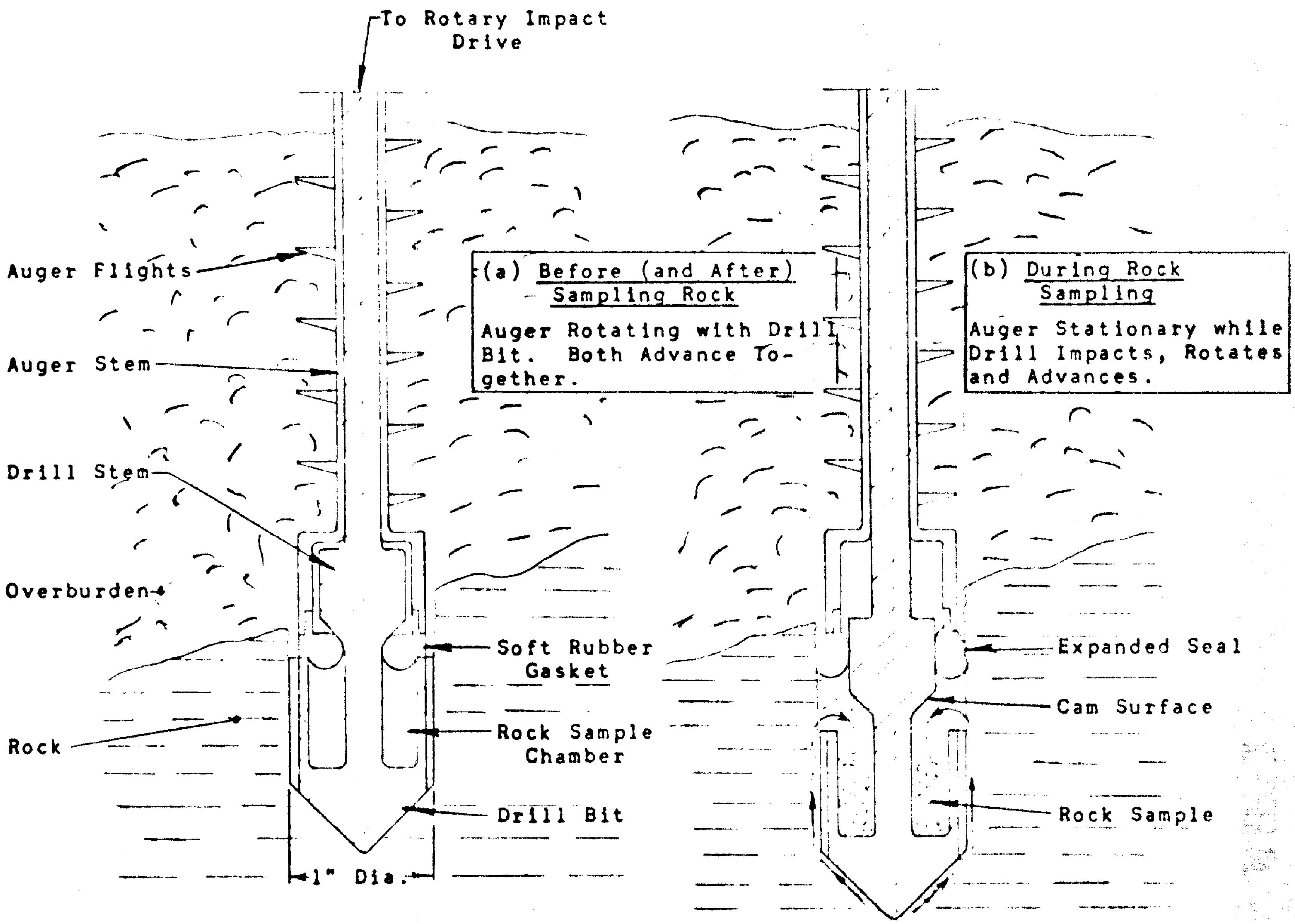
Both Bits Advance Together in Position Shown

(b) During Rock Fragmenting and Sampling

Core Bit Advances to Position Shown. Then Both Bits Advance Together Until Sample Chamber Fills

Batch Collector Concept (FM-8) with Gravity Rock Sample Acquisition

Figure 8



Batch Collector Concept (FM-9) with Overburden Auger and Expanding Seal

Figure 9

Task 1 - Acquiring the Overburden Sample

Task 2 - Transporting the Overburden Sample to the Surface

Task 3 - Gaining Access to the Rock Layer (Penetrating the Overburden)

Task 4 - Fragmenting or Penetrating the Rock Layer

Task 5 - Sealing Overburden Out of the Rock Sample

Task 6 - Acquiring the Rock Sample

Task 7 - Transporting the Rock Sample to the Surface

Some of these tasks were defined in Section 1.3 of Progress Report No. 2. The list presented herein is considered more complete and reflects problems pointed out at the J.P.L. design review.

The concepts may be separated into two major groups, those which transport rock particles to the surface in a continuous process, and those which collect a batch of rock particles and transport the batch to the surface. Tables I and II list the concepts in these respective groups by number* and show the method each employs to accomplish tasks 1 through 7.

It is evident from these tables that among the 9 concepts, there are only 3 or 4 different methods to accomplish each task. This is not surprising, since the concepts employing obviously poor methods to accomplish major tasks were eliminated in the initial evaluation discussed in our previous progress report.

3. Comparison of Concepts

In this comparison, emphasis was placed on pointing out special features, advantages and disadvantages of the concepts,

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*The original concept numbers (assigned in Progress Report No. 2) from which these concepts were evolved are also shown in Tables I and II as a matter of interest.

Table I

Methods Employed to Accomplis

Continuous Transpo

Current Concept No.	Evolved from Concept No.	Task 1 Acquiring Overburden Sample	Task 2 Transporting Overburden Sample	Task 3 Gaining Access to Rock Layer
FM-1	A-1	Drill induced particle flow up large internal ports.	Continuous Process. Kinetic energy of impeller impacts particles up casing into collection pan.	Continuous removal of overburden (same mode as overburden sample transport).
FM-2	A-15	Same as above	Continuous gas transport up casing. (Cyclone separator required)	Same as above
FM-3	A-19	Same as above	Same as above	Same as above
FM-4	A-11 A-16	Same as above	Same as above	Same as above

2

h Major Mission Tasks

rt Concepts

Task 4 Fragmenting Rock	Task 5 Sealing Overburden Out of Rock Sample	Task 6 Acquiring Rock Sample	Task 7 Transporting Rock Sample
Rotary impact bit without external flutes.	Depends on clearance between impact bit and sidewall, and induced particle flow pressure.	Drill induced particle flow up large internal ports.	Continuous Process. Kinetic energy of impeller impacts particles up casing into collection pan. (No separator required.) Purging of overburden required.
Same as above	Same as above	Same as above	Continuous gas transport up casing. (Cyclone separator required) Purging of overburden required.
Concentric rotary impact core bit and drill bit (2 pieces)	Stationary core bit face seals on cut ledge while rock sampling.	Same as above	Same as above
Rotary impact bit without external flutes.	Drill bit advances and cams expanding seal against hole sidewall.	Same as above	Same as above

Table II

Methods Employed to Accomplish

Batch Collection

Current Concept No.	Evolved from Concept No.	Task 1 Acquiring Overburden Sample	Task 2 Transporting Overburden Sample	Task 3 Gaining Access to Rock Layer
FM-5	A-13	Particle flow up external drill flutes, or by filling of chamber during drill stem extraction.	Positive mechanical transport by extracting drill stem.	"Passing through" overburden by minor compaction.
FM-6	A-22	Same as above	Same as above	Same as above
FM-7	A-2	Same as above	Same as above	Same as above
FM-8	A-18	Same as above	Same as above	Same as above
FM-9	A-14	Drill induced particle flow up external flutes, or filling of auger flights during extraction.	Sample transported up rotating auger flights.	Continuous removal of overburden by rotating auger.

2

RE ORDER No. 65-

Major Mission Tasks

Concepts

Task 4 Fragmenting Rock	Task 5 Sealing Overburden Out of Rock Sample	Task 6 Acquiring Rock Sample	Task 7 Transporting Rock Sample
Rotary impact drill bit with external flutes.	Depends on clearance between bit and sidewall, and induced particle flow pressure.	Drill induced particle flow up large internal ports. (Externally operated valves retain sample.)	Positive mechanical transport by extracting drill stem. (No purging required.)
Concentric rotary impact core bit and drill bit (2 pieces)	Stationary core bit face seals on cut ledge while rock sampling.	Drill induced particle flow up external flutes on drill bit.	Same as above
Rotary impact bit with external flutes.	Drill bit advances and cams expanding seal against hole sidewall.	Same as above	Same as above
Concentric rotary impact core bit and drill bit (2 pieces). Core fragmented by drill bit.	Rock sample produced far from overburden interface. Core bit also seals out overburden.	Particles produced above sample chamber and fall in by gravity.	Same as above
Rotary impact bit with external flutes.	Drill bit advances and cams expanding seal against hole sidewall.	Drill induced particle flow up external flutes on drill bit.	Same as above

rather than the selection of the best concepts. Without performing experiments or tests, it is difficult to meaningfully choose the best concepts from a select group.

The two major concept groups, continuous transport and batch collection are compared separately in Sections 3.1 and 3.2 respectively.

3.1 Comparison of Continuous Transport Concepts (FM-1 through FM-4)

3.1.1 Accomplishment of Tasks 1, 2, 3, 6 and 7

Concepts FM-1 and FM-2 through 4 differ in that the former employs the kinetic energy of impeller impact to transport particles to the surface (Tasks 2 and 7) while the latter 3 concepts utilize gas transport. A test would be required to determine the feasibility of Concept FM-1. Because it is unconventional this concept must be assigned a low confidence level prior to testing. If after testing the basic transport mode is proven feasible, the concept would be quite attractive because of its simplicity.

Concepts FM-1 through FM-4 all utilize the same particle flow path in accomplishing Tasks 1, 2, 3, 6 and 7; and Concepts FM-2, 3 and 4 all use exactly the same method of accomplishing these tasks. The basic differences between the latter 3 concepts are in the methods they utilize to seal overburden out of the rock sampling region (Task 5) and the required differences in drill bit configurations (Task 4) necessary for compatibility with the sealing methods employed.

3.1.2 Differences Between Concepts in Accomplishing Tasks 4 and 5

Concept FM-2 has no special sealing device for the annulus between the drill bit sidewall and the hole sidewall.* If this annulus is kept small, and if the particles produced by drill impact are driven up into this annulus, major

*This characteristic also applies to Concept FM-1.

contamination should not occur. However, without test drilling (which is beyond the scope of F.M.A.'s program), it is difficult to determine whether a special seal is necessary to prevent contamination of the rock sample by overburden leakage down the clearance annulus.

In the event a seal is deemed necessary, Concepts FM-3 and FM-4 provide two different approaches to this problem. The former concept employs a core drill bit which is held stationary against the rock ledge it previously produced, while the central drill bit advances to fragment the sample as shown in Figure 3. The latter concept employs a mechanically expanded rubber seal between the liner and the hole sidewall as shown in Figure 4. This seal is protected from abrasion before and after sampling since it is smaller in diameter than the drill bit and liner. During sampling it is expanded against the sidewall by a cam surface on the advancing drill stem. During sampling the liner is held stationary, and the seal is static against the rock sidewall. There is, however, relative motion between the seal and the drill stem as the drill bit advances.

The sealing method used in Concept FM-4 is expected to be more positive and reliable than that employed in Concept FM-3. However, it is questionable whether the contamination problem is serious enough to justify the complications necessary to incorporate either of the sealing methods.

3.1.3 Selection of the Best Continuous Transport Concepts

If a special seal <u>is not</u> deemed necessary to prevent overburden leakage down the clearance annulus between drill bit and rock sidewall, Concepts FM-1 and FM-2 are considered the best of this group. A choice between them would depend on test results for reasons previously explained.

If a special seal <u>is</u> deemed necessary, Concept FM-4 is considered the best concept of this group.*

*Concept FM-1 does not lend itself to easy incorporation of the expanding seal.

3.2 Comparison of Batch Collection Concepts (FM-5 through FM-9)

These concepts all accomplish rock sample transport (Task 7) by the same method. This method is considered as reliable as the drill extraction process, since once acquired the sample is confined in a collection chamber directly connected to the drill stem.

3.2.1 Accomplishment of Tasks 1, 2 and 3

Concepts FM-5 through FM-8 use the same methods for accomplishing Tasks 1, 2 and 3.

The methods used for accomplishing Tasks 1 and 2 are relatively positive and are considered reliable. It is likely that the overburden chamber would fill during extraction (if not during penetration) thus accomplishing Task 1. Once the sample is in the overburden chamber, transport (Task 2) is as positive as the drill extraction process.

The reliability of "passing through" the overburden with minor compaction to achieve Task 3 is doubtful if cohesive or very dense overburden were encountered. Tests would be required to determine the feasibility of this process in various simulated overburden materials.

Concept FM-9 has a better capability of achieving Task 3 since an auger has been incorporated to ease penetration of the overburden layer. Achievement of Tasks 1 and 2 is considered reliable since the auger flights could be "cupped" to retain an overburden sample during extraction if the sample were not transported to the surface during the penetration process. If the required auger speed could be matched to the rotational speed of the drill stem, the auger could rotate and advance together with the drill stem during penetration of the overburden. The auger could then be driven by the rotary impact drive mechanism, and uncoupled during sampling as shown in Figure 9(b).

3.2.2 Accomplishment of Tasks 4, 5 and 6

In this group of concepts the methods employed to achieve Tasks 4 and 5 were often dictated by Task 6 requirements. For this reason, Task 6 will be discussed first.

3.2.2.1 Accomplishment of Task 6 Acquiring Rock Sample

Concepts FM-6, 7 and 9 depend on drill induced particle flow up external flutes on the drill bit to acquire rock sample particles and thus accomplish Task 6.

Concept FM-5 also depends on drill induced particle flow, but employs large internal ports on the drill bit for sample acquisition. These ports have externally operated valves since simple check valves suited for operating with the very small particle forces available would be unreliable.

Concept FM-8 employs a markedly different particle acquisition process. It is the only concept (in both major groups) which does not depend on drill induced particle pressure forces to lift the particles for acquisition. Instead, the particles are produced above the acquisition chamber and thus fall into it. This is accomplished by fragmenting a core and collecting fragments in a chamber provided in the core bit. It is expected that particle size could be predetermined to some degree by varying the metering gap shown in Figure 8(b). Particles would then continue to be fragmented until they were small enough to pass through the gap.

3.2.2.2 Accomplishment of Tasks 4 and 5

The previous discussion of sealing methods in Section 3.1.2 is also pertinent when comparing batch collection concepts.

Concept FM-5 employs no special sealing device to achieve Task 5, because both the expanding seal and core bit seal were considered incompatible with the external valve actuation required.

Concepts FM-6 and FM-8 both employ the core bit sealing method. In the case of Concept FM-8 however, the core bit is primarily required to produce the configuration necessary for the gravity acquisition technique to be employed.

Concepts FM-7 and FM-9 both employ a mechanically actuated expanding seal to accomplish Task 5.

3.2.3 Selection of the Best Batch Collection Concepts

Concept FM-9 which utilizes an auger must be selected as the best concept of this group, if "passing through" the overburden with minor compaction is considered an unreliable method of gaining access to the rock layer. This follows because the rest of the mission tasks could not be performed if the overburden is not penetrated.

Concept FM-8 should be selected as the best concept of this group if rock particle acquisition by drill induced upward particle flow is considered unreliable. This follows because it is the only concept which does not depend on this phenomenon for rock sample acquisition.

A combination of Concepts FM-8 and FM-9 could be formed at the risk of introducing excessive complexity, by adding a rotating auger to Concept FM-8. This would combine the previously described unique features of both concepts.

Concept FM-5 has no special sealing device incorporated and could only be considered superior to Concepts FM-6 and FM-7 if the large internal ports and externally operated valves peculiar to it offer significantly higher particle acquisition reliability than the external flutes employed in Concepts FM-6 and FM-7.

Since the mechanically expanded overburden seal employed in Concept FM-7 is considered superior to the core bit seal employed in Concept FM-6 (see Section 3.1.2 for a discussion of these seals) and FM-6 offers no other significant advantages, Concept FM-7 would be considered the more promising concept of the two.

4. Conclusions and Recommendations

The selection of the best continuous transport and batch collection concepts was discussed in Sections 3.1.3 and 3.2.3 respectively. In these discussions selection alternatives were presented which are dependent on the predicted performance of the concepts in accomplishing one or more of the designated tasks.

The following conclusions and recommendations are based on our engineering judgment and our understanding of J.P.L. experience with rotary impact drilling.

a. Conservative practice indicates selection of Concept FM-4 as the most promising continuous transport concept since it provides a positive overburden seal, is relatively conventional, and sample acquisition by drill induced particle flow was deemed feasible by J.P.L.

b. Conservative practice indicates selection of Concept FM-9 as the most promising batch collection concept, since it provides a positive overburden seal, a particle acquisition method deemed feasible by J.P.L., positive overburden and rock sample transport, and is the only concept of this group which does not depend on compaction to penetrate the overburden.

c. Unless tests are conducted which justify the elimination of conservative design features, we recommend parallel development of Concepts FM-4 and FM-9.

d. In order to insure that device complexity is ultimately minimized, we further recommend that tests be conducted in the following areas:

   1. Penetration of overburden by passing through with minor compaction.

   2. The need for a special seal to preclude rock sample contamination by overburden leakage.

3. The feasibility of particle transport by the impeller impact method for use in short holes.
4. The particle flow performance of various drill configuration concepts.

APPENDIX B

HUGHES TOOL CO. REPORTS OF INVESTIGATION

B.1 - Gas Transport Through A Double Wall Tube.
Concepts 1, 1A, 2, 3, 4, 5

B.2 - Sampling By Use Of Calyx Basket.
Concept 6

B.3 - Lunar Sampling By Coring.
Concept 7

Lunar Sampling By Abrasive Coring.

Lunar Sampling By Abrasive Cutting.

B.4 - Sampling By Screw Conveyor
Concept 8

B.5 - Sampling By Vibrating Spiral Conveyor
Concept 9

B.6 - Soil Consolidation
Concept 10

B.7 - Removal Of Overburden By Electrostatic Repulsion
Concept 11

B.8 - Removal Of Overburden
Concepts 12, 12A, 13, 14, 15

B.9 - Double Wall Tube To Seal Overburden From Sample
Concepts 16, 19

B.10 - Sampling By Use Of Explosives
Concepts 17, 18, 18A

APPENDIX B.1

REPORT OF INVESTIGATION

GAS TRANSPORT THROUGH A DOUBLE WALL TUBE

Introduction

This investigation covers concepts 1, 1A, 2, 3, 4 and 5, gas transport in a double wall tube for a geological sample acquisition and transport device.

Investigation

The double wall tube concept using gas as the medium to transport the sample will meet the contract requirements provided that there will be rock to drill in and under the assumption that there will be no loss of gas to the formation. Concepts 1A, 4 and 5 have merit and would be able to transport the sample under the given conditions outlined above.

These concepts or devices will not perform satisfactorily when rock is not encountered. Generally in these concepts the outer tube is used to seal out the overburden and is also used either to transport the material up to the surface or act as the passageway for the gas to go down to the bit or pick up area. When the sample is to be taken from the overburden and the formation is porous, all of the concepts will allow leakage of gas to the formation. This leakage will be detrimental to the operation and success of the gas transport in a double wall tube.

The following concept by Mr. W. T. Jones and Mr. D. L. Imler is an attempt to solve the problem of obtaining a sample when rock is not encountered and the desired sample is obtained from a bed of particulate material. See Figure 1.

The operation is: after drilling to the desired depth to reach the sample and it is known that there has been no rock contacted, drill to an additional depth which will cover the spring and bellows. After this depth is reached the explosion bolts are fired and the spring and bellows will separate from the casing. Drilling will then continue and the sample will build up inside the casing. Gas will be diverted to the gas jets and blow the desired sample to the sample receiver. The one big assumption that was made was that there will not be a formation change from the sample location to a depth of approximately 1-6 inches below.

Figure 2 is a sketch of a concept by which the drill would drill dry as far as the drilled hole is concerned because there will be no flushing medium around the bit. This advantage will allow us to drill and collect the sample in the bed of particulate material and not lose gas to the surrounding formation. The drill will operate for a period of time long enough to fill the storage chamber. The drill is then pulled off bottom for a small distance and vibrated, this action will cause the material to fall off the bit spiral and allow the flapper value to close. Then gas is pumped or blown down the tube and the sample is lifted out.

Another device that would prevent leakage back to the hole past the bit is shown in Figure 3. In this operation the drill would operate in a continuous manner, that is the drill would not have to be stopped in order to transport the material as would be the case for Figure 2. As the drill advances material is accumulated inside the storage chamber. The vibrating drill imparts upward motion to the particles and as they pass out through the cone shaped nozzle they are picked up by the gas and transported to the surface.

The concepts as shown by figures 2 and 3 appear to be feasible. Laboratory testing will be required in order to determine if the concepts will work. The problem of contamination of the sample does not appear to be a problem with the vibrating drill stem and gas medium acting as self cleaning agents.

The weight of the gas and equipment necessary to provide for gas transport in a double wall tube can be approximated from the graph taken from Hughes Tool Company's 1960 Final Technical Report on Preliminary Feasibility Study of Drilling a Hole On The Moon. Four pounds mass would give us about 7.5 operating hours.

Conclusions

1. Concepts 1A, 4 and 5 would be able to drill and acquire the required sample in a non porous rock, but would probably not work in a bed of particulate material.

2. Laboratory testing will be required to evaluate the merits of the proposed systems as shown in Figures 1, 2, and 3.

3. Gas can not be passed through the drill bit and used as the transport device because of the possibility of drilling and taking a sample in the overburden. Thus the best method of getting a sample is with a system which uses a bit similar to the one developed by Hughes Aircraft. The system as proposed and shown by Figures 1, 2, and 3 uses such a drill bit.

4. The system as shown by Figure 3 has the most merit.

D. L. Imler

DLI:sjl

attachments (4)

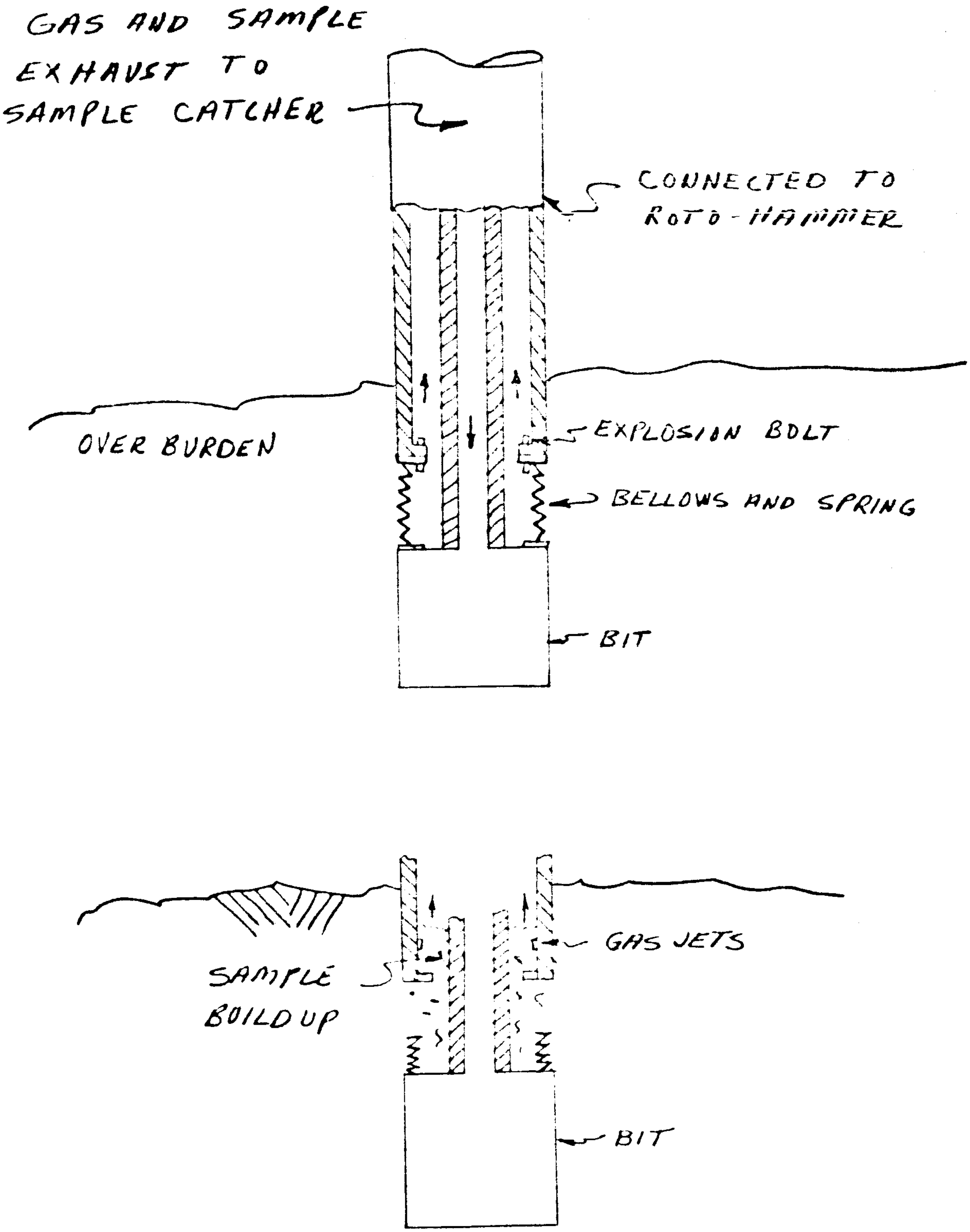


FIG. 1

4530 003-7 6-21-65

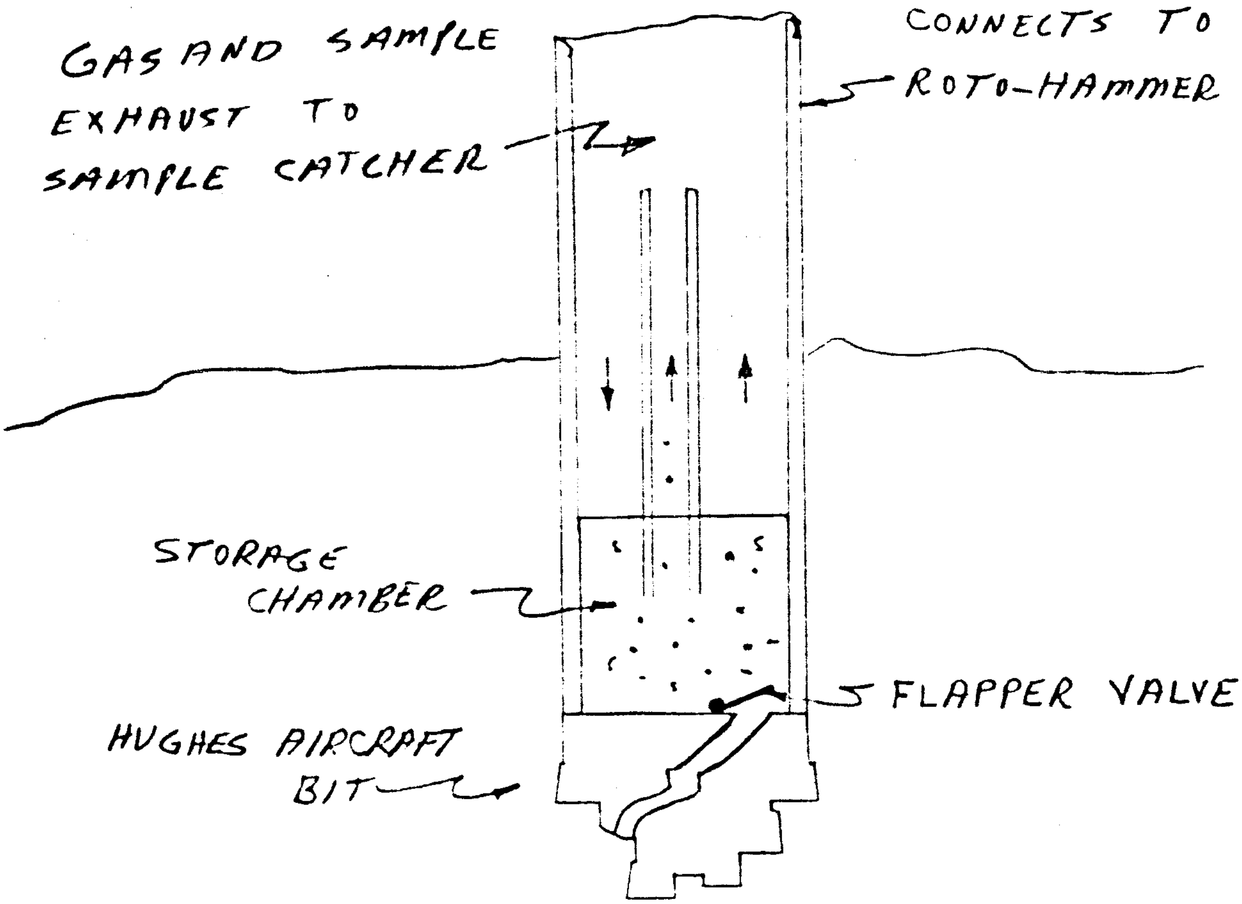


FIG. 2

4530 003-7

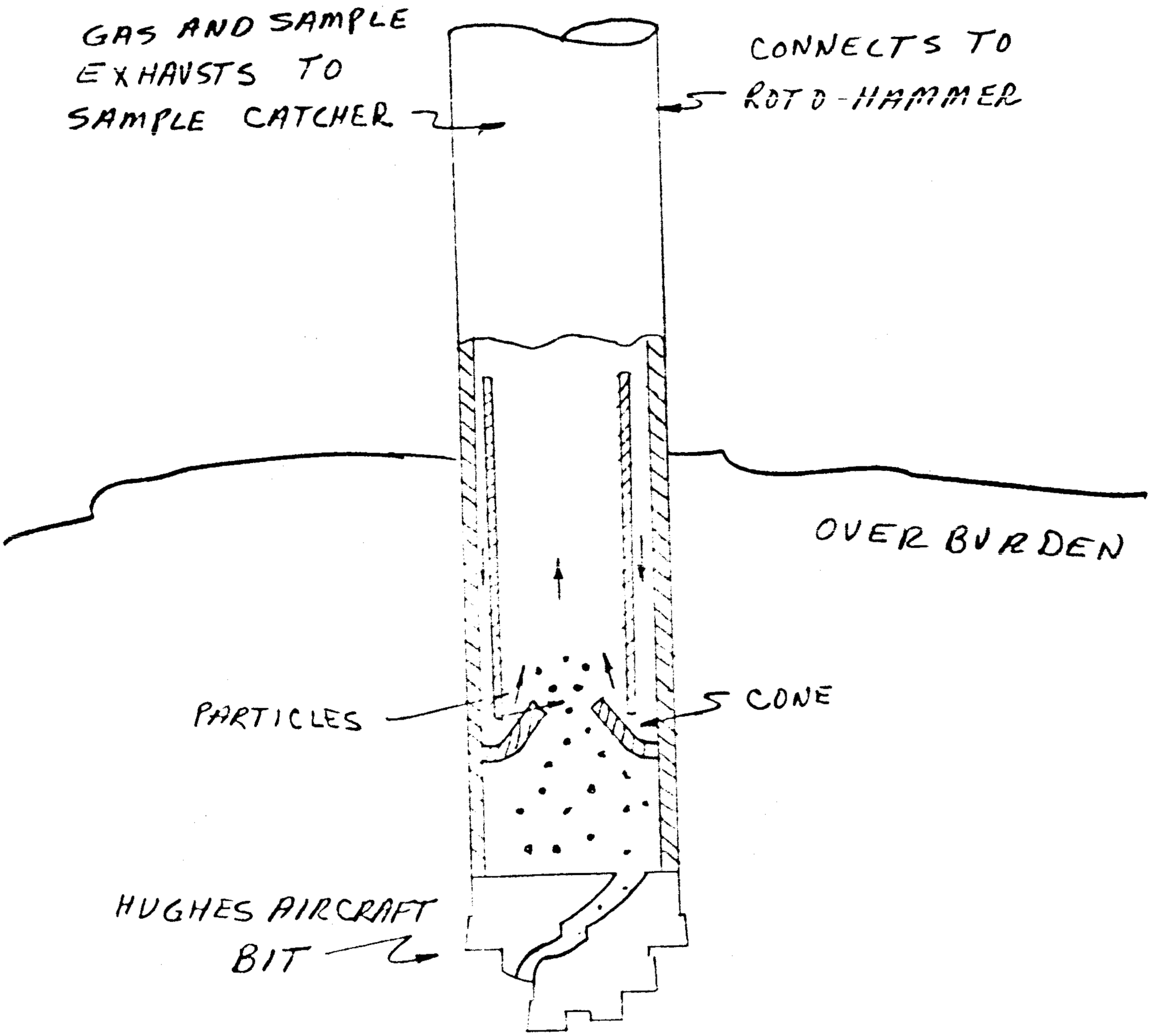
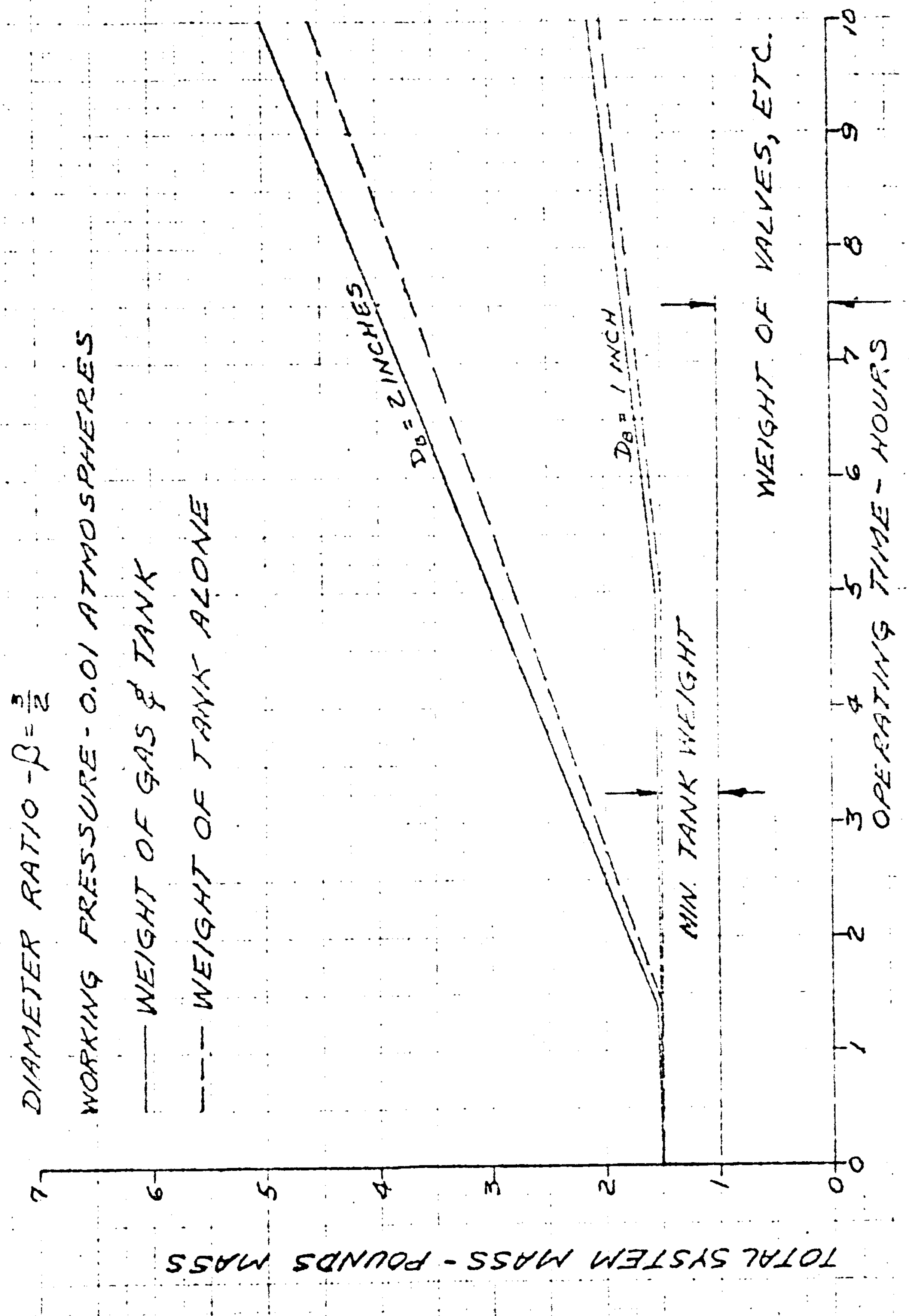


FIG. 3

45 30 003-7



MASS OF HELIUM GAS TRANSPORT SYSTEM

FIGURE C-13

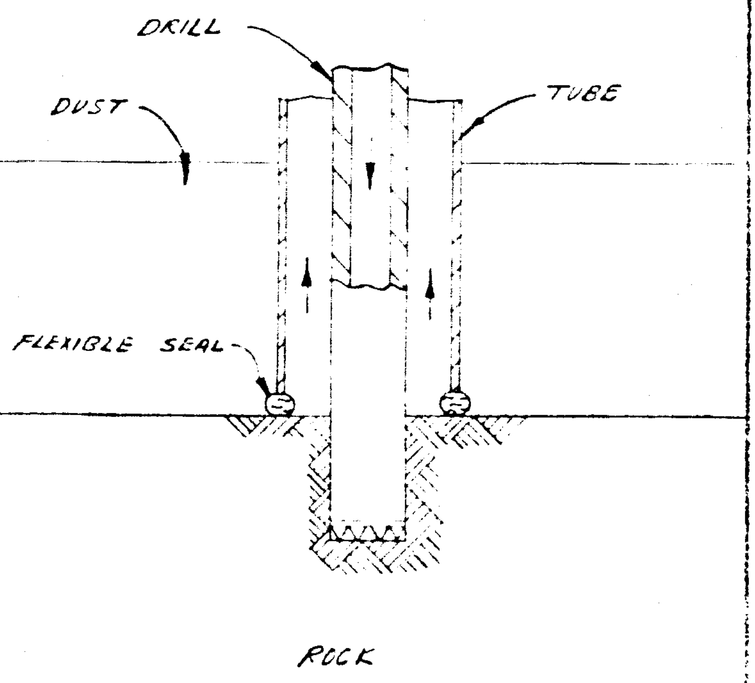
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: RCF

DESCRIPTION: COPPER LAM THRU DUST WITH DOUBLE WALL TUBE. BLOW DUST THRU TUBE. DRILL ROCK WITH PERCUSSION OR ROTARY AND BLOW SAMPLE OUT IN THE SAME MANNER AS THE DUST.

SKETCH:



ADVANTAGES: DUST EXCLUDED FROM SYSTEM. POSITIVE GAS PRESSURE INSIDE OUTER TUBE PREVENTS DUST LEAKAGE PAST SEAL.

DISADVANTAGES: PROBLEM OF OBTAINING COMPLETE SEAL WITH ROUGH ROCK SURFACE PARTICULARLY IF ROCK IS PUMICE.

DISPOSITION:

CONCEPT NO. 1

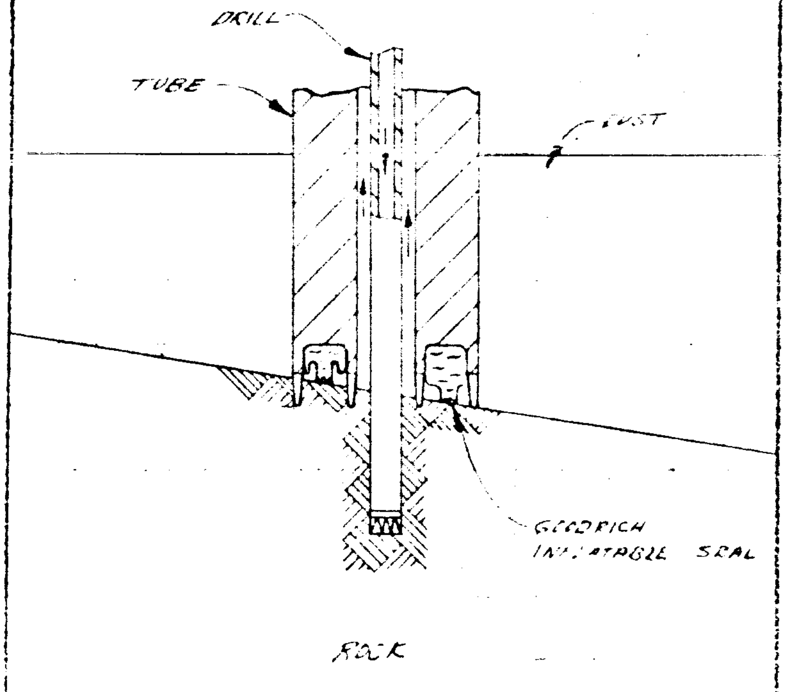
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: NTJ

DESCRIPTION: COFFER DAM THRU DUST. SEAT IN ROCK. BLOW DUST THRU TUBE. DRILL ROCK WITH PERCUSSOR OR ROTARY AND BLOW SAMPLE OUT IN THE SAME MANNER AS THE DUST.

SKETCH:



ADVANTAGES: ① SEALS AGAINST IRREGULAR ROCK. ② OUTER TUBE CAN BE SET INTO ROCK BASE BY HIGH-SPEED LOW-THRUST ROTARY MEANS. ③ SIMPLE DESIGN.

DISADVANTAGES: ① DOES NOT ABSOLUTELY EXCLUDE ALL CONTAMINANT FROM INSIDE TUBE, UNLESS DRILL BIT MEMBER CAN BE MADE TO ACT AS PLUG. ② TUBE WOULD HAVE TO BE RESTRAINED IN VERTICAL POSITION AGAINST INFLATABLE SEAL PRESSURE. ③ FALL BACK AND PRESSURE OF DRY OVERBURDEN MAY CAUSE A BUILD UP OF TORQUE ROBBING THE SEATING CAPABILITY SOME WHAT.

DISPOSITION:

CONCEPT NO. 1A

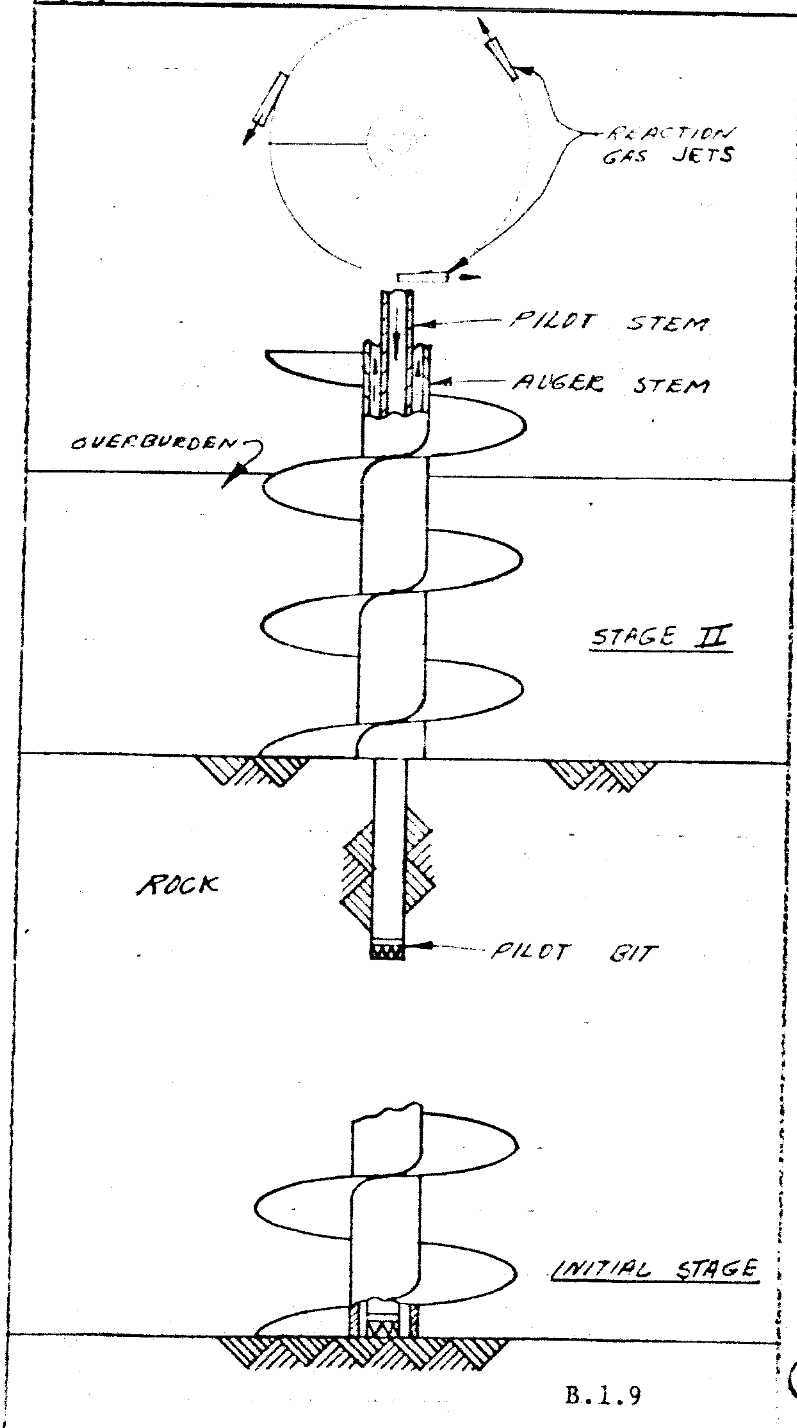
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: TNW

DESCRIPTION: AUGER WITH PILOT BIT IN HOLLOW AUGER STEM. PILOT GETS HARDPAN SAMPLE AFTER INITIAL STAGE. SEAL AT BOTTOM OF AUGER COULD BE AS REPRESENTED IN CONCEPT 1A. REACTION GAS JET DRIVE IS SHOWN, BUT MECHANICAL OR ELECTRICAL DRIVE COULD BE EMPLOYED.

SKETCH:



ADVANTAGES: (1) MINIMIZES THRUST REQUIREMENTS FOR SCREWING-IN OF CASING. (2) PILOT BIT ACTS AS PLUG THRU INITIAL STAGE KEEPING CONTAMINANT FROM SAMPLING TUBE. (3) PILOT BIT CAN BE ACTUATED AS DESIRED AFTER INITIAL STAGE (ROTARY OR ROTARY PERCUSSION). (4) AUGER OFFERS SOME SIDWISE STABILITY TO CASING AFTER SETTING.

DISADVANTAGES: DIFFICULTY OF SEATING AUGER INTO HARDPAN.

DISPOSITION:

CONCEPT NO. 2

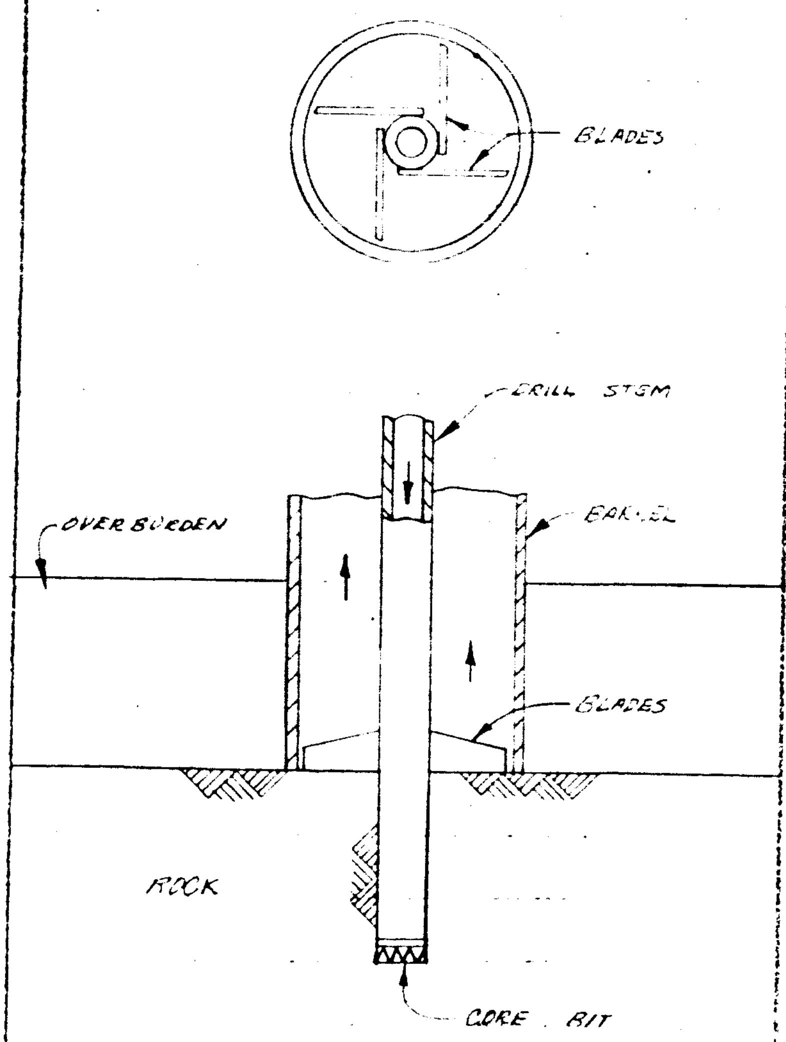
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-85 BY: WP

DESCRIPTION: BLADES AND AIR TO CLEAR OVERBURDEN FROM INSIDE OF BARREL. CORE BIT TO OBTAIN SAMPLE OF ROCK.

SKETCH:



ADVANTAGES: No SEAL REQUIRED BETWEEN BARREL AND ROCK; BARREL IS LARGE ENOUGH SO THAT DUST WHICH ENTERS SYSTEM BETWEEN BARREL AND ROCKS DOES NOT ENTER CORE BIT HOLE.

DISADVANTAGES: ① BLADES MUST CUT INTO ROUGH ROCK SURFACE TO INSURE THAT ALL DUST IS SCRAPED UP. ② DESIGN PROBLEM: GAS TRANSPORT SYSTEM. NEED TO INSURE ALL DUST IS TRANSPORTED OUT OF BARREL BEFORE SAMPLING. DURING SAMPLING NEED TO KEEP GAS IN CENTER OF BARREL TO INSURE THAT OVERBURDEN DUST IS NOT PICKED UP. ③ LARGE VOLUME OF AIR FLOW REQUIRED IN LARGE BARREL.

DISPOSITION:

CONCEPT NO. 3

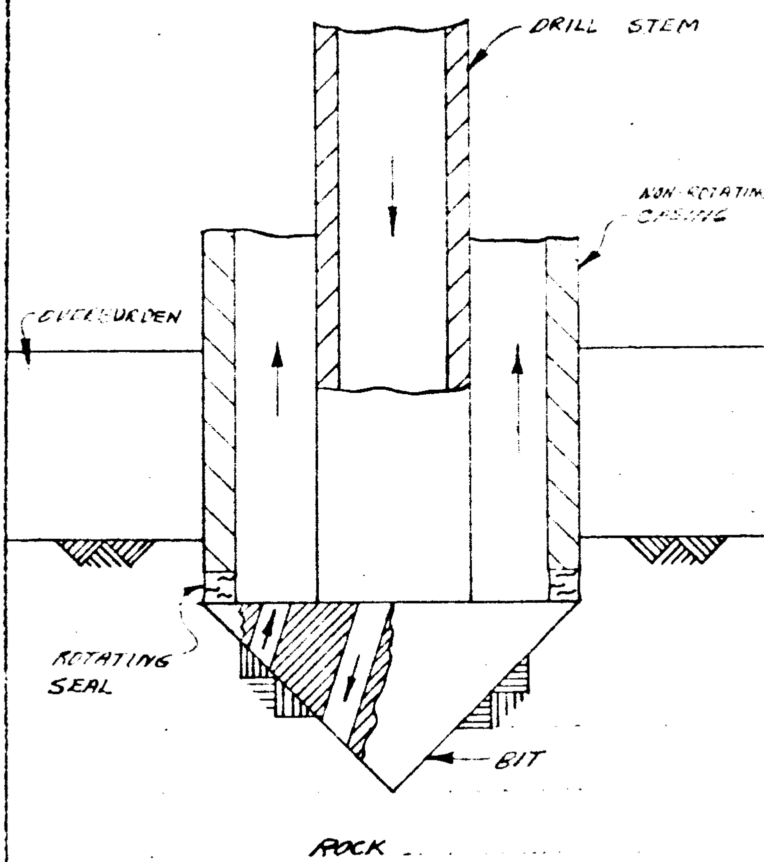
Concept Sheet

Geologic Sample Acquisition & Transport Device

Date: 4-27-65 By: DLJ

Description: Could sample overburden. Normally, overburden being blown out. When get to hardpan, torque sensors switches hardpan sample catcher into exhaust stream.

Sketch:



Advantages: ① Seal is maintained between two machined surfaces and therefore performance is easier to predict. ② Sample can be taken at any depth by putting filter in exhaust gas stream.

Disadvantages: ① Possible residual contamination of sample flow passage. ② Probably confines choice of drilling system to rotary. ③ Design problem: gas passage thru bit. ④ Possibility of gas leaking out thru formation still exist even though most of the gas system is inside the drill stem and casing.

Disposition:

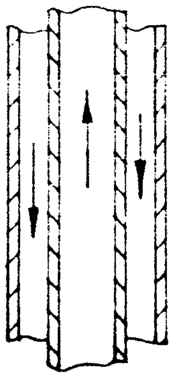
Concept No. 4

CONCEPT SHEET
GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-29-65 BY: ROE, SRS, RMD, VWP

DESCRIPTION: GAS TRANSPORT USING INERT GAS IN A REVERSE CIRCULATION SYSTEM.

SKETCH:

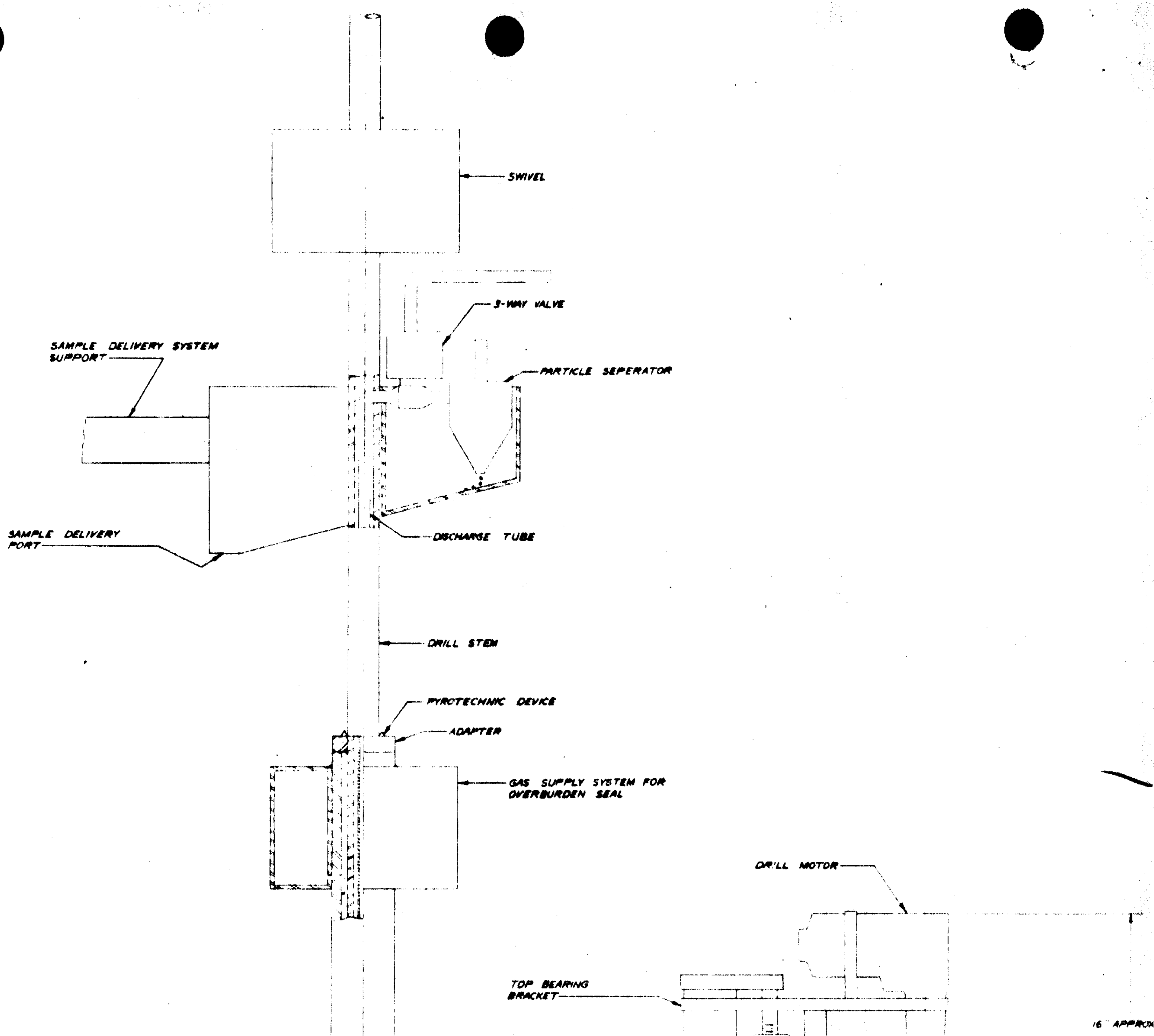


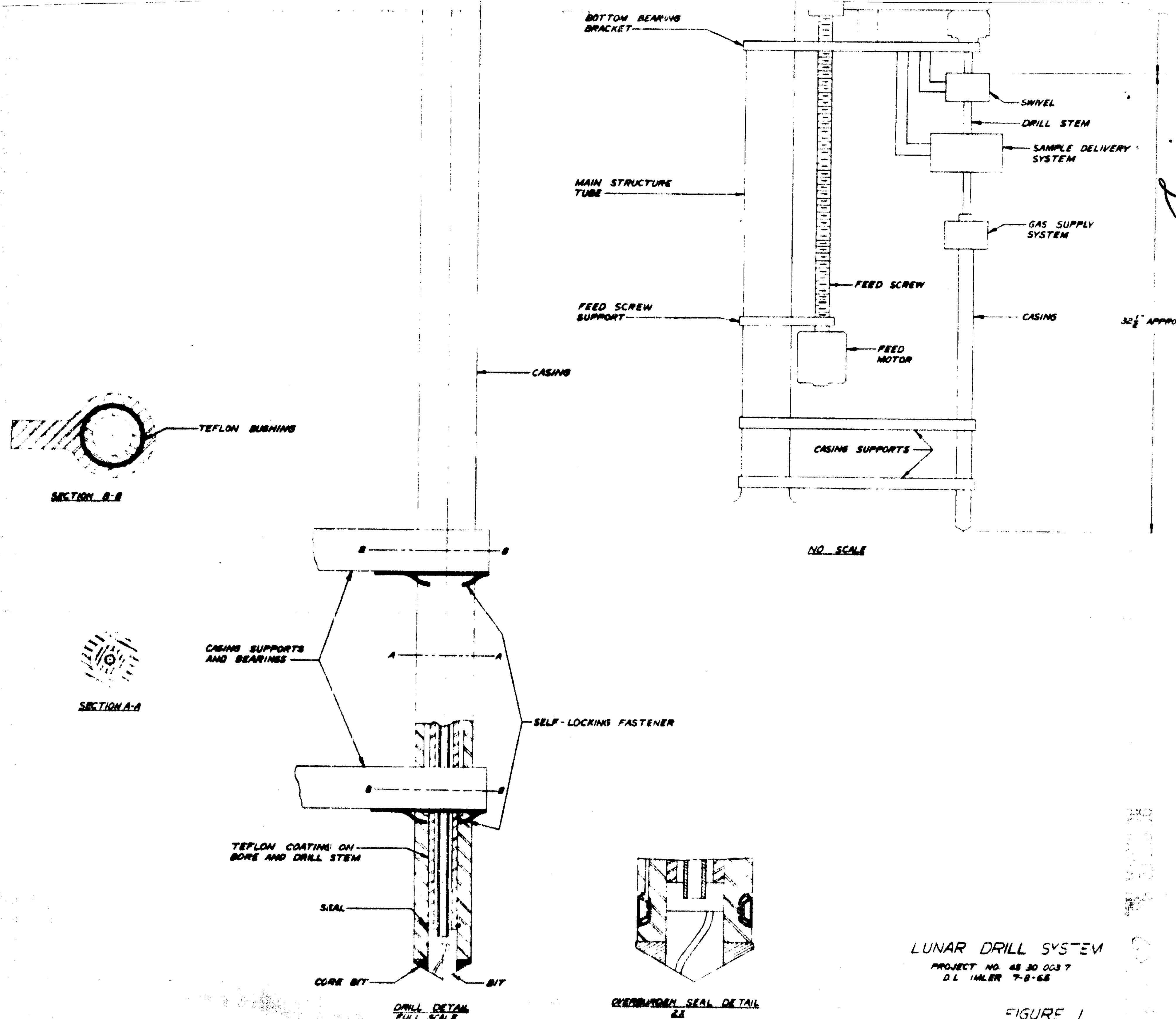
ADVANTAGES: ① MECHANICAL SIMPLICITY. ② CUTTINGS ARE LIFTED IN A SMALLER CROSS-SECTIONED AREA (AT LEAST IN CONVENTIONAL OIL WELL OR SHAFT DRILLING) AND THEREFORE REQUIRES A SMALLER CIRCULATION RATE.

DISADVANTAGES: ① POSSIBILITY OF LEAKAGE OF GAS OUT THRU POROUS FORMATION. ② ANY GAS TRANSPORT IDEA PENALIZES SYSTEM WITH STORAGE SYSTEM WEIGHT. WOULD PROBABLY HAVE TO BE A CRYOGENIC SYSTEM.

DISPOSITION:

CONCEPT NO. 5


SWIVEL
3-WAY VALVE
SAMPLE DELIVERY SYSTEM SUPPORT
PARTICLE SEPERATOR
SAMPLE DELIVERY PORT
DISCHARGE TUBE
DRILL STEM
PYROTECHNIC DEVICE
ADAPTER
GAS SUPPLY SYSTEM FOR OVERBURDEN SEAL
DRILL MOTOR
TOP BEARING BRACKET
16" APPROX



LUNAR DRILL SYSTEM

PROJECT NO. 48 30 003 7
D.L. IMLER 7-8-68

FIGURE 1

APPENDIX B.2

REPORT OF INVESTIGATION

SAMPLING BY USE OF CALYX BASKET

INTRODUCTION:

Concept No. 6 is described as follows: "Calyx basket in pilot hole to catch cuttings from a reaming drill". The basic thought of this concept was that the reaming of a pilot hole in hard basalt would require less energy than drilling a full hole.

INVESTIGATION:

Advantages cited center about the fact that this is a mechanical cuttings retrieval system, and as such requires no gas seals such as may be required in a gas transport system.

The disadvantages cited are well taken and would appear to be sufficient cause for rejection of the concept. In the first case, the production of the pilot hole itself in hard rock would pose the same problems we are attempting to alleviate by a reaming operation, except perhaps, the concern for contaminant exclusion. If a pilot hole must be produced at all, its cuttings could as well be used as the sample, without the added complexity of a reaming operation.

If indeed, the use of a reaming operation and collection of cuttings in a basket would assure an uncontaminated sample, further development would be in order. However, Disadvantage (2) appears to be an unsurmountable problem, particularly if the reaming operation is to be done by percussive drilling.

As presented, Concept No. 6 appears to offer the advantage of extreme simplicity. However, it is depicted in an intermediate stage of operation. Considerable complexity is added when provision is made for achieving this stage. In fact, a solution for achieving this stage is not immediately evident.

CONCLUSIONS:

Concept No. 6 does not merit further consideration.

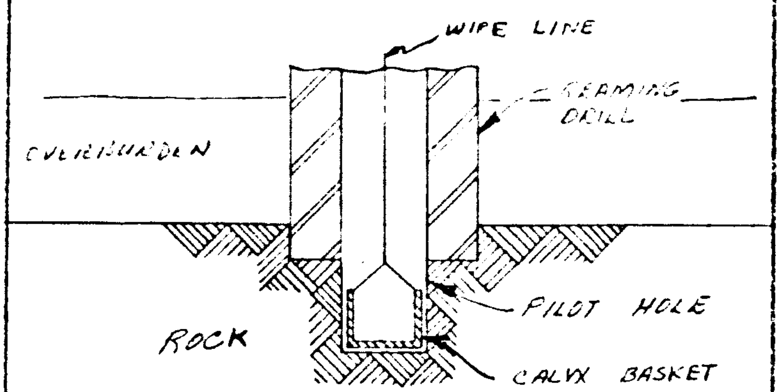
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: SRS

DESCRIPTION: CALYX BASKET IN PILOT HOLE TO CATCH CUTTINGS FROM REAMING DRILL.

SKETCH:



ADVANTAGES: ① REQUIRES NO GAS SEALS. ② NO LOST CIRCULATION PROBLEM IF ROCK IS POROUS.

DISADVANTAGES: ① PILOT HOLE MUST BE DRILLED DEEPER THAN DEPTH OF SAMPLE. ② POSSIBILITY EXISTS FOR SOME OVERBURDEN DUST PARTICLES TO WORK THEIR WAY DOWN TO DRILLING FACE OF REAMING DRILL, UNDER IT, AND INTO CALYX BASKET.

DISPOSITION:

CONCEPT NO. 6

APPENDIX B.3

REPORTS OF INVESTIGATION

LUNAR SAMPLING BY CORING

INTRODUCTION:

This investigation relates primarily to Concept No. 7, which states, "Obtain solid core, then bring it up thru dust. Use air and/or vibration to blow off dust". Feasibility of this concept may be examined by dividing into four phases:

(1) Producing the core, (2) Breaking the core, (3) Retrieving (transporting) the core, (4) Cleaning the core.

The presumption is made that the capability of coring in rock as hard as basalt is required.

INVESTIGATION:

1. Producing the core. A classification of coring methods follows:

   A. Rotary

      (1) Carbide tipped tool — Ref. (1)
      (2) Diamond tool — Ref. (1)

   B. Punch — Ref. (2)

   C. Sidewall — Ref. (2)

   D. Cable tool — Ref. (2)

   E. Chip — Ref. (2)

   F. Percussion

In practice, the most popular and highly developed is rotary coring with diamond tools. Methods B, D, and F are basically similar in that each involves the successive pounding of the coring tool against the formation. These three methods will be discussed as a group. Method C, sidewall coring, will be treated in Concept 18A. Chip coring is presumed to be outside the scope of Concept No. 7, inasmuch as this concept depends on the production of one large piece of rock, or at worst, several, so that the surface area exposed to possible

RE-ORDER No

contamination is held at a minimum. So, this investigation is concerned primarily with Method A, rotary coring, and some form of Methods B, D, and F.

Rotary coring was examined in the light of reasonably presumed limitations on device weight, thrust, and power (20 lb. earth weight, 50 watts continuous, 50 lb. max. thrust). Reference (1) is cited, referring to a 1" dia. carbide coring bit: "Carbide tipped coring drills were the only rotary drills that would penetrate granite without a cooling and flushing medium. These drills penetrated quite slowly and dulling of the bit was quickly evident. Shortly after the start of drilling in a particular hole, power consumption would drop because the now duller bit would take a smaller bite. Power and penetration rate would then remain constant until that point in the drilling cycle where the drill dulled completely". At 50 lb. thrust and 250 rpm, this 1" dia. carbide coring tool required 8 min. to cut 0.25" depth. At 50 lb. thrust and 735 rpm, it required 8 min. to cut 0.37" depth. In the first case, power consumption was about 125 watts, and in the latter, about 310 watts, continuous. In both cases, little additional penetration was being experienced after 8 minutes. Presuming a core diameter of 3/4", approx. 1/2" length would have to be successfully recovered and processed to meet the 3 cc. sample volume requirement.

One of the musts for diamond drilling or coring is a sufficient supply of cooling medium, normally water or drilling mud. See References (2) and (3). Ref. (1) cites tests of a 1" dia. diamond core bit in marble and granite using an adequate cooling and flushing medium. With 45 lb. thrust in marble and at 900 rpm, 4-1/2" were drilled in 2 minutes. To quote Ref. (1), "Diamond core drills were then evaluated in granite specimens using a 50 lb. thrust and no cooling or flushing agent. The drill bits quickly burned, polishing the diamonds without making any significant penetration. One diamond bit was then fluted - - - - - - -. Two brief tests were run in sandstone with a flow of cooling air and one in granite without cooling air. All runs lasted one minute or less". "Although no additional consideration was given to diamond core drilling, it remains possible that certain advantages may accrue if a bit were fabricated, particularly for the non-cooled task".

Percussion coring (related Methods B, D, F) may offer possible advantages for the "non-cooled task" mentioned above. The basis is taken from Ref. (1) which states, in the section on Rotary Drilling Solid Carbide Bits, "Several 1" to 1-3/8" dia. solid drills with carbide bits were experimentally evaluated in samples of concrete, Berea Sandstone, and Gabbro granite - - - . Even at drill thrusts as low as 24 lb., concrete and sandstone were penetrable. - - - - However, when it was attempted to penetrate granite, no significant penetration was made at drill loadings up to 160 lb". When similar drills were used in rotary impact, a 1" dia. drill penetrated granite at a rate of approx. 7-1/2" depth in 8 minutes, with no appreciable dulling, at a power level of 550 w. In a coring operation, and for the depths required, it would be expected that power requirements could be lessened considerably.

Additionally, percussion coring may well be compatible with the lunar drill already developed. Several deterrents exist, however. A design for the percussion core drill would have to be developed. This would probably take the form of carbide shapes disposed in a circumferential manner. Diamonds, due to their low impact strength, would not be suitable. Another possible drawback is the questionable ability to get unbroken cores of sufficient length. However, in this application in basalt, where the length need not be over 1" at most for a 3/4" dia. core, the chances of getting a single core would appear to be good consistent with favorable rock continuity.

2. Breaking the core. Assuming that a core of 1/4" to 3/4" dia. has been successfully produced, in solid basalt, with no convenient discontinuity present to assist breakage, an estimate was made of the tensile load required to break such core at its base. Little data is available on tensile strength of rock. However, Reference (4) gives 2550 psi for North Carolina diorite, 410 to 1030 psi for various granites, and 860 psi for Maryland marble. Based on an arbitrary 1000 psi tensile strength, 1/4" dia., 1/2" dia., and 3/4" dia. cores would require approx. 50 lb., 200 lb., and 450 lb. pull, respectively, to break. It would appear absolutely inconsistent with weight and power requirements to consider tensile breaking of cores larger than 1/2" dia.. In fact, 1/2" dia. appears questionable.

Another possibility of breaking the core would be by wedging against its top end, or providing a bending moment with the maximum moment occurring at the base of the core. Required moments would be ~~1/5~~ 1.5 lb. in., 12.5 lb.in., and 42 lb.in., for 1/4", 1/2", and 3/4" dia. cores, respectively, based on 1000 psi tensile strength. Assuming a wedge angle of 30° (anything smaller would get into the range of possible problems with respect to sufficient axial movement to effect an adequate lateral forcing displacement) and resolving force components, and assuming a maximum downward wedge force of 50 lb., it would appear quite possible to break cores of 1" length and up to 3/4" dia., dependent upon frictional characteristics of the wedge application mechanism. However, it should be recognized that radial spatial requirements to build such a device would be extremely stringent.

3. Retrieving (transporting) the core. Assuming Phases 1 and 2 can be achieved, Phase 3 requires a core catching mechanism to retain the core in the barrel during withdrawal. If the core remains intact, a simple wedging split ring mounted on an inner tapered surface inside the coring bit can be made to hold the core. See Ref. (3) p.265. If the core is dust, or rubble, or in small pieces, some other, as yet unknown, means would have to be developed. I see nothing but almost insurmountable problems in attempting to devise a universal device to fit all possible situations, without benefit of intelligent monitoring and control.

If the sample can be withdrawn, and the bottom of the core barrel is open, the same percussion drilling system could be used for removing it from the barrel, simply by withdrawal, disposing the bottom of the core over a hard, elongated probe (tungsten carbide perhaps) mounted vertically in the center of a sample catching pan, and feeding downward against the probe with the percussive drill actuated. This should break the core into sufficiently small pieces to permit shaking it from the barrel. This method presumes an ability to effectively purge the core barrel and core of contaminant dust <u>before</u> fragmentation (see next section).

4. Cleaning the core. Upon withdrawal of the core barrel with its captive core from beneath the overburden, it could possibly be inserted into a purge chamber, where purge gases could be circulated in such a manner, while operating the percussive mechanism, as to exhaust the residual dust from the entire coring device and core to the lunar atmosphere. This could be done with a minimum of high pressure gas, in intermittent spurts, to conserve gas. Gas requirements to effect this cleaning should not be excessive. I visualize the indexing mechanism to be essentially three positions: (1) drilling, (2) cleaning, (3) dumping. Here again, this method would not work on a dust sample, but should work reasonably well on an intact core sample or one which is in relatively large pieces.

<u>CONCLUSIONS</u>:

1. The foregoing discussion presumed the coring bit to be in position on top of the hardpan. Means would have to be devised to get it in such position. Possibly a soft bull plug held in place with soft shear pins would effectively keep the core barrel clean to this point. The drill stem would have to be rotated, or vibrated thru the overburden, with dust or rubble being moved upwardly with purging gas in the annulus. Upon reaching the hardpan, the pins could be sheared, and the bull plug could ride on top of the resulting core. The problem of getting the device to hardpan is judged to be one of considerable difficulty, inasmuch as various types overburden material would have to be negotiated, and control thru such diverse material could not be easily achieved. Development tests would be required.

2. If coring of any sort is to be accomplished, it must be by percussion means. This fortunately, may be quite compatible with the already available percussion drill.

3. Breaking of cores by wedging (bending) rather than pulling would appear to be feasible. This conclusion depends upon development of radial spatial design relationships not currently known.

4. Cleaning of the core may be achieved by sporadic gas blasts, presuming that the core is essentially intact or in large pieces. Dust or rubble samples could not be cleaned in this manner.

5. Transporting and retrieving intact cores could be achieved, by vibrating against hard metal probes disposed over the sample pan. Dust or rubble samples could not be accommodated.

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Lunar Sampling by Coring

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2. Arthur W. McCray and Frank W. Cole, Oil Well Drilling Technology, Univ. of Okla. Press, 1959, Chapter 16, "Coring".

3. J. D. Cumming, Diamond Drill Handbook, J. K. Smit and Sons of Canada, Ltd., 1951.

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CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: VWP

DESCRIPTION: OBTAIN SOLID CORE, THEN BRING IT UP THRU DUST. AFTER IT IS ABOVE DUST, USE AIR AND/OR VIBRATION TO BLOW OFF DUST

SKETCH: NONE

ADVANTAGES: ① CORE DRILLING REQUIRES LESS POWER THAN FULL FACE DRILLING. ② PROBLEM OF COMPLETELY SEALING OUT DUST IS ELIMINATED.

DISADVANTAGES: ① IF ROCK IS BASALT, PROBLEM IS TO BREAK CORE. ② IF ROCK IS PUMICE, PROBLEM IS TO OBTAIN ONE PIECE CORE RATHER THAN MANY SMALL PIECES. ③ IF ROCK IS PUMICE AND OVERBURDEN DUST IS VERY FINE, PROBLEM WILL BE TO GET ALL OF DUST OUT OF THE EXPOSED VESICULES.

DISPOSITION:

CONCEPT NO. 7

APPENDIX B.3

LUNAR SAMPLING BY ABRASIVE CORING

INTRODUCTION:

Reference is made to the Report of Investigation, "Lunar Sampling by Coring", and Concept No. 7 which states, "Obtain solid core, then bring it up thru dust. Use air and/or vibration to blow off dust". This report is to examine an additional possible method of producing a core, that of abrasive cutting.

INVESTIGATION:

Sand-laden fluids have been extensively used for various oilfield applications such as perforating thru casings, open-hole cleanup and well bore enlargement, as an aid to hydraulic fracturing, horizontal or vertical cutting of casing or tubing, removal of cement or bridge plugs, and drilling of rat or mouse holes in hard rock. Reference 4. The magnitude of the operation and equipment involved in these applications would preclude its application in lunar sampling work without extensive scaling-down and attendant development work. For example, a single-stage, triple orifice jet gun used for a well notching operation required 8000 lb. of 20-40 mesh sand in 6400 gal. of gelled water at 150 gpm and 2600 psi. Ref. 4 .

A further "feel" for the capability of sand-laden fluid streams to penetrate various rock formations is obtained from Tables from Ref. 1 . General recommendations were made. The maximum nozzle pressure drop

TABLE 1 - TEST POINTS FOR GRANITE

	Point 1	Point 2	Point 3
Cutting Time (min)	95	3	18
Penetration (in.)	10.5	2.4	4.5
Nozzle Δp (psi)	3200	3200	2000

TABLE 2 - MAXIMUM PENETRATIONS CALCULATED FOR GRANITE AS A FUNCTION OF NOZZLE DIFFERENTIAL PRESSURE.

Δp Nozzle (psi)	V th* (ft/sec)	max at $t = \infty$ (in.)
2000	41.5	14.6
2500	41.5	16.4
3000	41.5	17.9
3500	41.5	19.4
4000	41.5	20.7

*Threshold Cutting Velocity

TABLE 3 - MAXIMUM PENETRATION IN INCHES (OPEN-HOLE AND $t = \infty$). Based on EQ. 16

Material	H** (CT Scale)	V th*** (ft/sec)	Nozzle Differential Pressure (psi) 2000	2500	3000	3500	4000
Basalt, Nephelite, Austin, Tex.	19	41.5	14.6	16.4	17.9	19.4	20.7
Quartzite, Roanoke, Va.	19	41.5	14.6	16.4	17.9	19.4	20.7
Granite Biotite, Barre, Vt.	19	41.5	14.6	16.4	17.9	19.4	20.7
Granite, Quartz Monzonite, Milford, N. H.	18	39.3	15.5	17.3	18.9	20.4	21.9
Schist, Muscovite, Charlottesville, Va.	17	37.1	16.4	18.3	20.0	21.7	23.2
Limestone, Siliceous, Coyote, Calif.	17	37.1	16.4	18.3	20.0	21.7	23.2
Sandstone, Ferruginous, Shreveport, La.	14	30.6	19.9	22.2	24.3	26.3	28.1
Limestone, Dolomite, Joliet, Ill.	14	30.6	19.9	22.2	24.3	26.3	28.1
Marble, Calcite, Ball Ground, Ga.	11	24.0	25.3	28.3	21.0	33.5	35.8
Marble, Siliceous, Texas, Maryland	8	17.5	34.7	38.8	42.5	45.9	49.1
Sandstone, Bituminous, Provo, Utah	6	13.1	46.4	51.8	56.8	61.4	65.6
Limestone, Bituminous, Ravia, Okla.	3	6.55	92.7	103.7	113.6	122.7	131.2

**Hardness (Int'l. Crit. Table Scale)
***Thres. Cutting Velocity

consistent with safe practice should be used. The tool should be designed for stand-off distances of 6 nozzle diameters or less. Sand ratios in the range from 1 to 2 lb./gal should be used. A relief perforation should be performed to improve penetration characteristics.

The possibility was suggested that sand-laden air or gas streams at high velocity could be used to produce the core. An inquiry was directed to the S. S. White Co. regarding their Industrial Airbrasive Univ. Ref. 3. This unit uses high velocity plant air or bottled CO_2 at approx. 80 psi operation pressure, and 27 to 50 micron aluminum oxide or silicon carbide powders directed thru tungsten carbide or sapphire nozzles. A 12 oz. charge of powder will last approx. 1 hour, and gas consumption at 75 psi is about 1/3 cfm.

In evaluating the capability of such a unit to make a core in basalt, a nozzle tip distance of .197" was presumed which would produce a cut of .025" dia. moving the nozzle in a 1/2" dia. circle to produce a 1/2" dia. core, and estimating a cutting rate of 50 milligrams of material removed per min., approx. 1/2" depth cut would have to be made to assure a 3 cc sample (assuming some core loss in retrieval). This depth cut would require approx. 20 minutes and consume about 7 cfm of gas and 200 grams of abrasive powder, based on production rates presented for ceramics.

Presuming that access to the hardpan can be obtained thru the overburden, this method offers a possible attractive alternative to percussion coring. However, the same problems with respect to breaking the core (2) and retrieving the core (3) discussed in the IOC of 6-14-65 still remain. Therefore, the simplicity inherent in the "Airbrasive" system would be partially nullified if it becomes necessary to subsequently enter into the kerf with a core breaking and retrieval mechanism. On the other hand, it does not appear infeasible to design a combination core-cutting, core under-cutting, core breaking, and retrieval tool which can perform all of these operations once access to the hardpan is attained thru a casing system.

In all probability, supplementary gas would have to be supplied to remove abrasive particles and cuttings. An attractive possibility is that the gas used provides an adequate contaminant to prevent adhesion of particles in the hole or on tool surfaces.

The commercial model Airbrasive unit could provide a basic starting point, but major modifications would have to be made to meet parameters.

CONCLUSIONS:

The Airbrasive system may be an attractive shock-free substitute for percussion coring. The writer feels that this system bears further investigation.

BIBLIOGRAPHY - REPORT OF INVESTIGATION

Sampling by Use of Abrasive Coring

1. R. W. Brown, J. L. Loper, "Theory of Formation Cutting Using the Sand Erosion Process", Journal of Petroleum Technology, May 1961, pp. 483-488.

2. F. C. Pittman, D. W. Harriman, J. C. St. John, "Investigation of Abrasive - Laden - Fluid Method for Perforation and Fracture Initiation", Journal of Petroleum Technology, May 1961, pp. 489-495.

3. Bulletin 6407A and 6404, S.S. White Industrial Division, "The S. S. White Industrial Airbrasive Unit". Also communication Mr. Dow Harter to W. T. Jones, 5-10-65.

4. R. S. Ousterhout, "Field Applications of Abrasive-Jetting Techniques", Journal of Petroleum Technology, May 1961, pp. 413-415.

APPENDIX B.3

LUNAR SAMPLING BY ABRASIVE CUTTING

INTRODUCTION:

At the July 13 and 14 design review, it was suggested that the "Airbrasive" method be evaluated as a possible technique for application in a lunar geologic sampling system. Reference is made to Report of Investigation in which "Airbrasive" was evaluated as a method to produce cores. Its use in a coring method was held to be attractive, but the coring method itself was discarded as being too difficult to apply and with no capacity to acquire dust or rubble samples.

INVESTIGATION:

An examination of the geometrical aspects connected with application of this technique indicated the first problems. In use of the S.S. White Airbrasives unit (Ref. 1) on which this analysis will be based, a standard .018" diameter nozzle, with a .590" nozzle tip distance (NTD) produces a hole .079" in diameter. This hole diameter is sufficient to provide clearance for the nozzle tip (.052" dia.) and provide an annulus for return gas and cuttings flow. The length of .079" dia. hole required to produce a 3 cc sample, presuming a punch-type operation is employed, would be

$$L = \frac{3cc \times 6.102 \times 10^{-2}\ \frac{in^3}{cc}}{\frac{\pi}{4}(.079)^2\ in^2} = 37.4\ in.$$

Normal nozzle tip length of the White Airbrasive unit is 3/16".

Based on cutting speeds in ceramics, which are arbitrarily taken as being roughly equivalent to cutting speeds in basalt, 90 milligrams of material may be removed in one minute. Presuming that the constant NTD of .590" can be maintained (to insure hole diameter), approx. 110 minutes would be required to punch the 37.4" deep hole.

Conceivably, the nozzle tip size may be enlarged to enable the acquiring of the desired sample size without going to the improbable depth of 37". Thus, if orifice size were doubled, and it is presumed that hole size is accordingly doubled, material removed per unit depth would be quadrupled, and the required depth would be approx. 9" - 10". However, gas flow, and probably abrasives flow, requirements would be increased by a factor of four. In spite of these increased flow requirements, abrasive and gas volumes do not appear to be unreasonable.

The technique of sampling by abrasive cutting was also examined in light of the many other requirements of the geologic sample acquisition and transport device. These included: (1) ability to penetrate overburden to rock, (2) ability to sample overburden, (3) ability to acquire rock sample, (4) ability to transport sample, (5) complexity, (6) sample sorting, and (7) sample contamination.

Requirements (1) and (2) preceding, appear to offer rather formidable obstacles to use of an Airbrasive type unit, at least in its commercial form. Regarding (1), a long thin nozzle could be easily forced thru under-dense overburden to the proximity of the hardpan. However, in cohesive overburden, this capability may be seriously hampered. In order to protect the nozzle so as to ensure its capability in bedrock, it would appear mandatory that access to the bedrock be achieved thru a previously emplaced casing. Thus, an inherently simple system is made more complex by the casing requirement. Additionally, the overburden sampling requirement is still not satisfied, and would probably have to be provided by an auxiliary system.

The abrasive particles which are used in this cutting system are in the order of 10 to 50 microns in size. This is within the range of desired sample particle size. It is possible that the abrasive particles are readily distinguishable as known sample contaminant by the analytical device. On the other hand, if it is proved to be desirable to separate abrasive particles from rock particles, some sort of separating system would have to be provided, compounding complexity.

CONCLUSIONS:

Application of the Airbrasive system to lunar sampling appears to be much too complex to warrant further consideration.

ROB:am

BIBLIOGRAPHY - REPORT OF INVESTIGATION

Lunar Sampling by Abrasive Cutting

1. Bulletin 6407A and 6404, S.S. White Industrial Division, "The S.S. White Industrial Airbrasive Unit".

APPENDIX B.4

REPORT OF INVESTIGATION

SAMPLING BY SCREW CONVEYOR

INTRODUCTION:

This investigation covers the use of an auger or screw conveyor as a geologic sample acquisition and transport device.

INVESTIGATION:

Laboratory testing of an auger by Joy Manufacturing Company (1) yields the following information:

(1) Effect of pitch:

The larger the pitch the higher the rate of transportation for any given auger speed. This increase has a decreasing tendency as pitch increases.

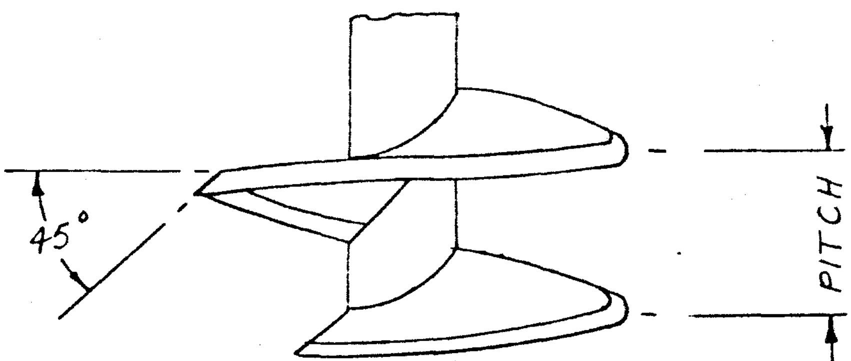
(2) Effect of flight roughness:

Increasing surface roughness decreases efficiency of transportation.

(3) Path of chip travel:

Chips move slightly up the flight while generally moving radially outward to the sidewall, and then up the flight along the side wall.

(4) Effect of flight shape:



Putting a 45° on the edge of the auger increased the rate of transportation.

(5) Effect of number of flights:

A double flight auger removes less material than a single flight auger.

(6) Effect of moisture content:

Dry sand pours easily and greatly increases leak back around the auger flight. Damp loam does leak back somewhat but in general transports very well. Very wet loam sticks together and is removed in chunks, a higher auger speed is required to start effective transportation.

(7) Effect of bearing area:

Increasing the contact area of soil and side wall greatly increases the evacuation rate.

(8) Effect of time:

The evacuation rate remains fairly constantly high in the early stages of evacuation and then tapers off as the flights are emptied.

Additional tests showed that the $45^{\circ}\measuredangle$ on the auger flights had a greater leakage than the standard auger. They did not recommend the use of the $45^{\circ}\measuredangle$.

The relationship between the auger size and speed, the various friction factors, the auger helix angle and the particle path has been determined (2).

The equation for the minimum speed at which the auger can be rotated and still have material feeding up its flights is:

$$R\omega^2 = g\,\frac{\mu_p}{\mu_w}\,\frac{(\mu_p + \tan\theta)}{(1 - \mu_p \tan\theta)}$$

Where R = auger radius

ω = angular speed of auger

μ_p = friction coefficient between particle and plane

μ_w = friction coefficient between particle and wall

θ = helix angle

The graph on Page 4 shows the relationship of the minimum rotary speed necessary to transport material up the flight with the coefficient of friction. This graph is for the given condition of a 1/2 inch diameter auger with a pitch of 1/8 inch. An examination of the equation shows that by reducing the pitch and holding the other variables constant the rpm necessary to transport the material is reduced. The pitch though, can be reduced only to the smallest value which still will let material pass up the auger flights. The optimum pitch for a given auger diameter and material will have to be experimentally determined.

On the lunar surface, a 200 rpm auger would transport material which had a coefficient of friction of approximately 1.5.

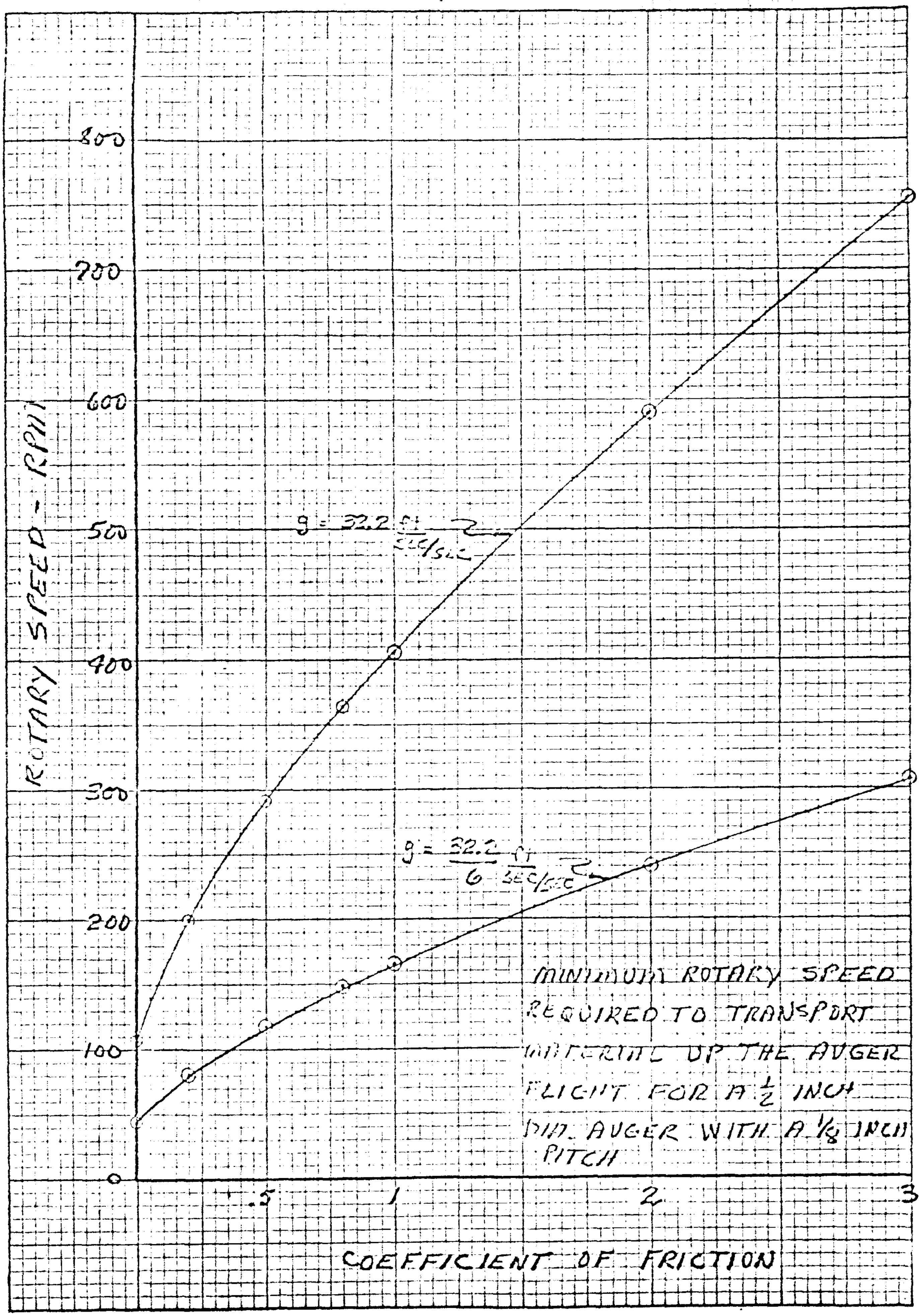
This concept would allow the sample to be received without contamination from the surrounding terrain. The concept is relatively simple. The concept could be an integral part of the lunar drill i.e. the screw conveyor system could act as the drill stem.

The variables that will affect the operation and success of the auger or screw conveyor are:

1. lunar environment
2. coefficient of friction
   (a) between auger and casing
   (b) between auger flight and material
3. rotary speed of conveyor
4. auger design
5. size and type of material
6. size of hole to be drilled
7. power required to transport the material

The path of material travel in an auger is: the particles move slightly up the auger flight while generally moving radially outward to the sidewall, and then up the flight along the side wall. Generally there is leakage past the auger flights due to the clearance between the auger and the wall of the hole or casing. This leakage will be aggravated if the auger is vibrated as would the case if the auger were an integral part of a percussive type tool.

The auger sample transport concept appears to have considerable merit. Considerable experimental work will be necessary to determine the effects of the lunar environment on the operation of the system. Present knowledge about the lunar surface material and the effect of a high vacuum on the working of the system leaves much to be desired.


ROTARY SPEED - RPM
800
700
600
500
400
300
200
100
0
g = 32.2 ft/sec/sec
g = 32.2/6 ft/sec/sec
MINIMUM ROTARY SPEED REQUIRED TO TRANSPORT MATERIAL UP THE AUGER FLIGHT FOR A 1/2 INCH DIA. AUGER WITH A 1/8 INCH PITCH
.5
1
2
3
COEFFICIENT OF FRICTION

DLI 6-9-65

The system as I envision it would consist of a drill bit which produces the transported material and projects it onto the auger flight, the auger flight and casing and a deflector to deflect the transported material to a device which transports it to the analyzer. The complete system will have a few design problems namely:

1. Getting material away from bottom of hole.
2. Movement of material from bottom of hole up and upon the auger flights.
3. Prevent leakage of material around auger flights if the device uses a percussive type drill.

CONCLUSIONS:

1. The auger sample transport concept is feasible.
2. Effectiveness of the transport system will have to be determined through experimental tests.
3. Tests could be made in conjunction with model to be built for concept #9.

The advantages of the auger transport system are:

1. Can be used on a percussive type tool as well as rotary. This advantage is in effect concept #9.
2. Simplicity.
3. Reliable.

The main disadvantage would be the long testing and development program necessary to arrive at the best design which would meet all the necessary requirements.

BIBLIOGRAPHY:

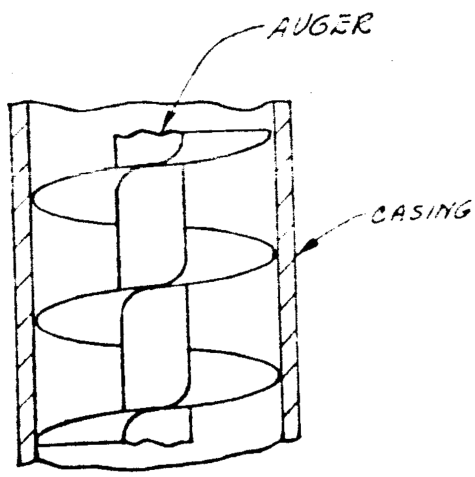
1. "Mobile Automatic Earth Drill" by Joy Manufacturing Co. Project No. 8-07-07-102; Contract No. DA-44-009 ENG. - 2518 dated Auguest 31, 1956.
2. "The Preliminary Design of a New ADH Hole Digger" by Foster-Miller Associates, Inc. dated April 15, 1960.

CONCEPT SHEET
GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: [illegible]

DESCRIPTION: AUGER FOR SAMPLE TRANSPORT. SCREW CONVEYOR. TWIST DRILL.

SKETCH:



ADVANTAGES: NO LOST CIRCULATION PROBLEMS IN PORUS ROCK OR OVERBURDEN.

DISADVANTAGES: (1) PARTICLES ARE MOVED UP SCREW CONVEYOR BY CENTRIFUGAL FORCE. SMALL PARTICLES COULD FALL INTO SPACE BETWEEN FLIGHTS AND CASING. SAMPLE WOULD THEN BE SORTED. (2) WOULD PARTICLES STICK TO FLIGHTS IN VACUUM

DISPOSITION:

CONCEPT NO. 8

APPENDIX B.5

REPORT OF INVESTIGATION

SAMPLING BY VIBRATING SPIRAL CONVEYOR

INTRODUCTION:

This investigation covers the concept of a vibrating spiral conveyor for a geological sample acquisition and transport device.

INVESTIGATION:

This study was made in conjunction with the study of Concept #8, a spiral conveyor for the geological sample acquisition and transport device. Library and literature searches back to the year 1960, produced little information on the subject of vibrating screw type conveyors.

Laboratory tests of a vibrating screw conveyor by the Jet Propulsion Laboratory (1) have shown that the vibratory principle is feasible.

A sketch of a proposed bread board model is attached. The system would consist of a Skil model 726 Roto-Hammer (2) supplying the basic rotary and hammering motion, an auger attached to the drill bit, and a casing encompassing the auger. The advancement into the formation would be provided by a motor driving a feed screw which is attached in a fashion to the casing.

The operation would be:

1. The Roto-Hammer would supply the rotary and impact motion to the auger.
2. This motion is transmitted through the auger to the bit.
3. Cuttings produced by the bit are transmitted by the bit up to the auger.
4. The auger transmits the cuttings up the flights and generally adjacent to the casing wall.
5. Cuttings from the auger flights are passed out through the ports in the casing wall.

An attempt was made to see if the casing and bit could be united as a single unit. It was thought that there has to be relative motion between the auger and the casing, but this might not be the case if the system is vibrated. A feasible system with the casing and bit as a unit was not found. Systems considered were:

1. Auger rotating at a higher rpm than the casing and bit through the use of a gear system.
2. Auger rotation through the use of an external power system.

The system as proposed appears feasible. Two problems or weaknesses stand out. The first is the problem of the separation of the bit and the casing after the impact of the hammer. This separation might allow material outside of the drilled hole to enter into the material transport stream. It will have to be experimentally determined if the separation of the bit from THE casing will be detrimental and allow foreign material into the transport system. The auger will rotate at 520 rpm and the hammer will strike 2400 blows per minute. The second problem is how to keep the auger clean or free from overburden contamination just before it is desired to take a sample. Possible solutions to this problem are as follows:

1. Use gas
2. Use a liquid
3. Mechanical device
   (a) Wiper
   (b) Brushes
4. Use separate drill to drill to sample location
5. Vibrate the auger

The drill stem assembly, which will consist of the auger, the bit, and the casing, will probably not come apart due to the fact that the bit will be attached to the auger and the casing will not slip past the bit or the upper assembly i.e. (attachments to spacecraft, transport device to analyzer, etc.). Since the drill stem assembly will not come apart the only feasible solution would be to vibrate the auger and shake the material off of the auger flights. It is hoped that the majority of the material can be disposed of in this manner and the resultant sample to be more than 95% pure.

An additional solution would be to drill deeper than required and the desired sample would act as the cleansing agent. This solution makes the assumption that there will not be a formation change while drilling to the additional depth.

A representative of the Syntron Corporation said that he did not know of a single manufacturer who made a vibrating screw conveyor that might be used in the vertical position. Nearly all of the screw conveyors are made to operate in the horizontal position. He thought that it would be difficult to get one to work satisfactory. Searches through the manufacturers advertisements in the various composite catalogs indicate that there are no manufacturers making vertical vibrating screw conveyors. There is a company making a vibrating screw conveyor used as a bin feeder (3). Additional time spent searching the catalogs and contacting companies would be of little value in the concept analysis.

CONCLUSION:

1. The vibrating spiral conveyor appears feasible.

2. Two problem areas exist. These problems do not appear to be too formidable.

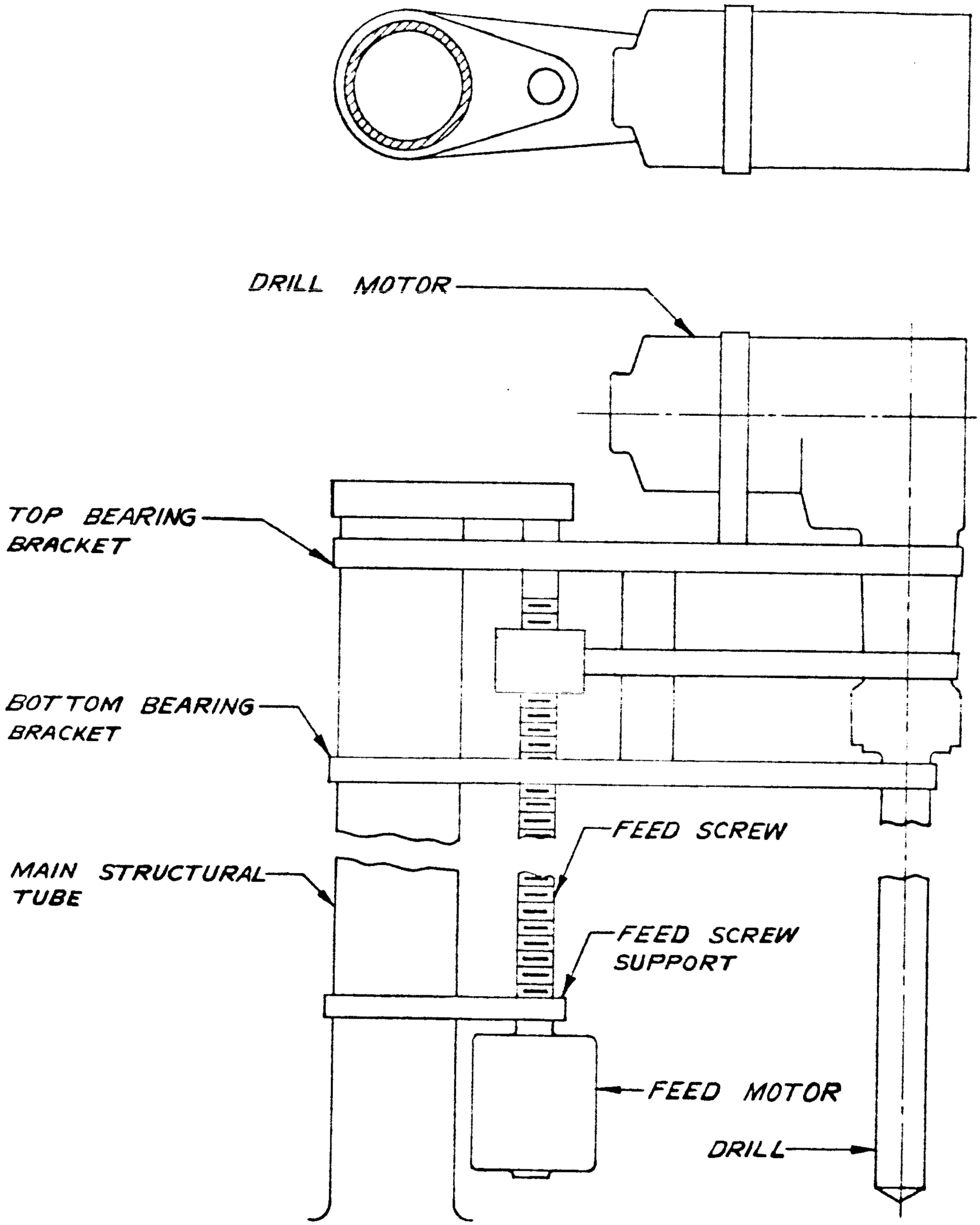
   (a) Contamination during period when casing and bit are separated.
   (b) Contamination on auger flights.

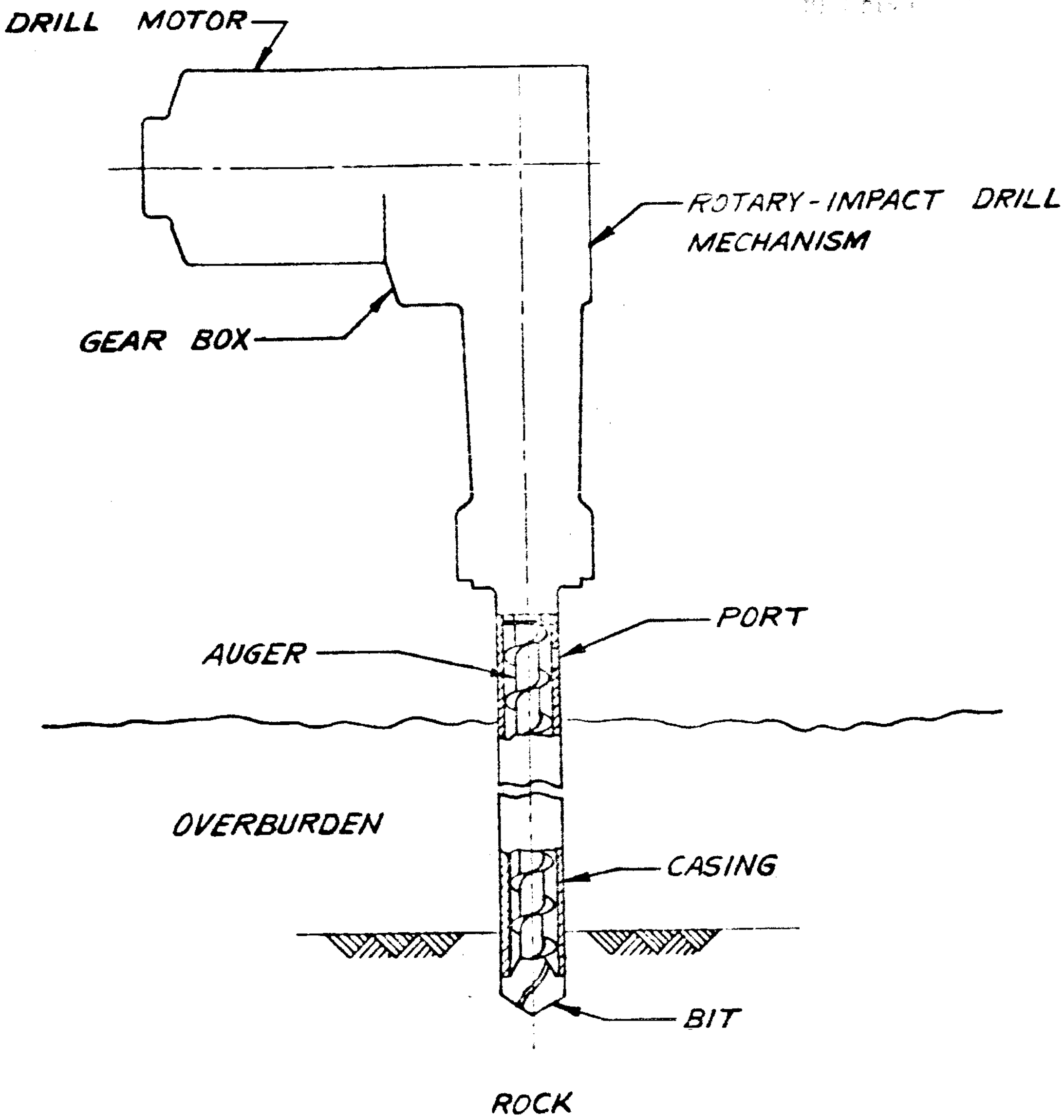
BIBLIOGRAPHY:

(1) Space Programs Summary No. 37-31, Volume VI, Jet Propulsion Laboratory, January 31, 1965.

(2) Skil Corporation, 1965 Industrial Catalog.

(3) Vibra Screw Feeders, Inc.
157 Huron Avenue, Clifton, New Jersey.


DRILL MOTOR
TOP BEARING BRACKET
BOTTOM BEARING BRACKET
FEED SCREW
MAIN STRUCTURAL TUBE
FEED SCREW SUPPORT
FEED MOTOR
DRILL


DRILL MOTOR
ROTARY-IMPACT DRILL MECHANISM
GEAR BOX
PORT
AUGER
OVERBURDEN
CASING
BIT
ROCK

CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-85 BY: WTJ

DESCRIPTION: VIBRATION FEED MATERIAL UP SPIRAL.

SKETCH: None

ADVANTAGES: ① NO LOST CIRCULATION PROBLEMS IN POROUS OVERBURDEN

DISADVANTAGES: ① THIS TYPE CONVEYOR USUALLY REQUIRES EXPERIMENTATION WITH TYPE OF MATERIAL TO BE TRANSPORTED IN ORDER TO DETERMINE THE FREQUENCY OF VIBRATION. ② QUITE LIKELY THAT SORTING WOULD OCCUR DURING ASCENT.

DISPOSITION:

CONCEPT NO. 9

APPENDIX B.6

REPORT OF INVESTIGATION

SOIL CONSOLIDATION

INTRODUCTION:

This report covers the investigation of Concept 10 which states "Consolidate dust around drilling site by freezing, chemical means, or grouting".

INVESTIGATION:

Concept 10A, which is the same principle as Concept 10, was immediately discarded since it was felt that the disadvantages listed on the concept sheet far outweighed any advantages.

Freezing the ground around a shaft sinking site has been used to advantage on earth to stabilize the soil. Since the surface of the moon receives heat from the sun by radiation, shading of the surface should drop the temperature far enough to freeze a liquid. Gold [1] cites measurements by Pettit and Nicholson (June 14, 1927), Pettit (October 27, 1939), and Strong and Sinton (July 26, 1953) of the lunar surface temperature during eclipses. These data show that within approximately one hour, from the time of entering the penumbra, the surface temperature drops from 350-400 °K to less than 200°K. Broner and Lander [2], in referring to the Pettit and Nicholson measurements, state "changes in lunar temperature occur very rapidly. During the eclipse the minimum temperature was reached 20-30 minutes after the sun had ceased to illuminate the moon's surface". Jaeger [3] also stated that the temperature drop at a spot on the surface which moved from sunlight to shadow would be very rapid. However, the problem of stabilization by freezing involves more than surface freezing; the overburden has to be frozen to a depth of up to one foot. Jaeger [3] gives the thermal conductivity of the lunar soil as 2.5×10^{-6} cal/cm sec °c at the surface and 2×10^{-4} cal/cm sec °c at a depth of a few millimeters. Muhleman [4] gives the thermal conductivity as 10^{-6} to 10^{-5} cgs units. Bernett et al [5] have determined the thermal conductivity of simulated lunar soils to be of the order of 10^{-5} cal/cm sec °c. This value of about 10^{-5} for the thermal conductivity is very low; hence, there would be a considerable time lag between a temperature drop on the lunar surface and the resulting subsurface temperature drop. The data cited by Gold [1] indicate roughly a drop of 150°K/hr on the surface while Broner and Lander [2] state "...subsurface temperatures fall at a rate of 8 to 10 deg K per hour". Kopal [6] states "...the diurnal variation in temperature at a depth of one foot already amounts to less than one-third of its surface range and the effects of diurnal heat waves do not make themselves felt till after a time lag of some 80 hours". Thus surface shading cannot be relied on to provide freezing temperatures to a depth of one foot in a relatively short time.

In addition to the heat transfer problem, there is still the problem of finding a liquid to use as the freezing medium. The hard vacuum precludes the use of fluids normally used in freezing applications. Also the fluid would undoubtedly have to be stored in a controlled environment chamber during the flight to the moon to prevent excess evaporation and freezing. Because of all these problems no further effort was expended on soil consolidation by freezing. If consolidation offered any hope of success it was felt that it would be in the area of grouting or chemical consolidation.

A survey [7,8] of methods used in chemical consolidation indicated that injection of chemicals to react with the overburden would be unsuitable for this application. Knowledge of the soil is necessary to specify the chemicals and the quantity to be used. Lambe [8] describes several types of grout, all of which are used commercially on earth and which have their own set of problems. Of the grouting materials described, only AM-9 seemed to have a possibility of working in the lunar environment. On earth it can be used in the widest range of soil types and soil particle sizes. In particular it can be used in soils of smaller particle size than any of the other grouts.

Karol and Mark [9] describe AM-9 and its use in obtaining extremely precise samples of unconsolidated soils. AM-9 is a chemical grout manufactured by the American Cyanamid Company. The AM-9 itself is a dry powder of acrylic monomers which dissolves rapidly in water. When catalyzed with a specially developed reduction-oxidation system, it gels in a predetermined length of time by forming cross linked polymers. In the tests described in this paper, thirty-five changes in soil strata were recorded in a forty-foot hole using AM-9 chemical grout. Only 10 feet away in another hole using conventional techniques only 10 changes in soil were recorded in fifty feet.

The local American Cyanamid representative was contacted to learn more about AM-9. Since this was to be an application in a completely different environment, the representative had no idea of whether AM-9 would be suitable or not. A laboratory kit and technical data for earth applications were supplied to us for testing.

A test was run in low pressure drying chamber. The gage on the chamber indicated that a 29.8 inch Hg vacuum was pulled, but undoubtedly there is some error in the gage itself. Results of this test did not look discouraging. Chemicals were mixed to give a gel time of 20-25 minutes. Gelling occurred at 22 minutes. Weight loss is shown in Figure 1. At the end of 33 hours the gel was still in one piece, but after being left in the vacuum overnight it had broken up as shown in Figure 2, which is a view looking down into the beaker containing the gel.

Another test was run in a vacuum furnace which is capable of producing a 6×10^{-5} mm Hg vacuum. Chemicals were mixed to provide a 20 minute gel time. The pressure in the chamber lowered gradually to 120 microns in thirty minutes; it then rose suddenly to almost atmospheric. After another 30 minutes the pressure had dropped only to 450 microns so the test was terminated and the sample removed from the vacuum chamber. Ice had formed on the surface of the AM-9 which was still a liquid. Rapid evaporation at the surface had cooled the rest of the liquid thereby extending the gel time to the order of 200 minutes rather than the calculated 20 minutes. After being in the atmosphere for about forty minutes, gelling occurred. Because of the rapid evaporation of the water in a vacuum, AM-9 is not suitable for use on the moon, and further searching for a suitable grout will not be done at this time.

During this investigation the use of a grouting or sealing material around the bottom of a casing sunk thru the overburden as shown in Concept 19 of Group 1 was kept in mind. No grouting material has been found, but the application shown in Concept 19 does not require a grout, only a seal. The sealant does not have to penetrate between the particles of overburden; it just has to keep the overburden particles from getting inside the casing. One possible materials for the sealant is low vapor pressure grease. Riehl [10] ran weight loss tests on several materials. He found that duplicate samples of Dow-Corning QC-20093 Fluorosilicone grease had a 3.2 and 2.6% weight loss respectively within the first eight hours of exposure to vacuum on the order of 10^{-5} to 10^{-7} mm Hg. No further weight loss was recorded up to 25 hour exposure.

The main problem in using grease as a seal is the ambient temperature. Heaters will probably be required in the grease storage chamber to keep the grease viscous enough to flow. Once the grease leaves the storage chamber, however, it must pass thru a small diameter hole down to the bit. This long (relative to diameter) passage will have been exposed long enough to have reached ambient temperatures. At these temperatures the grease probably will not flow thru the small hole.

During the contractor's preliminary design presentation to JPL, the following idea was mentioned. Unconsolidated particles larger than 300 microns present a problem. They are too large to get good results from the X-ray diffractometer. They cannot be comminuted in place by a drilling device because of their non-cohesive characteristics. A separate flail to comminute the particles adds complexity. By consolidating a comparatively large volume of this overburden with a resin or grout, the drill could be used to reduce the size of these particles while the individual particles were held in the matrix of the resin or grout.

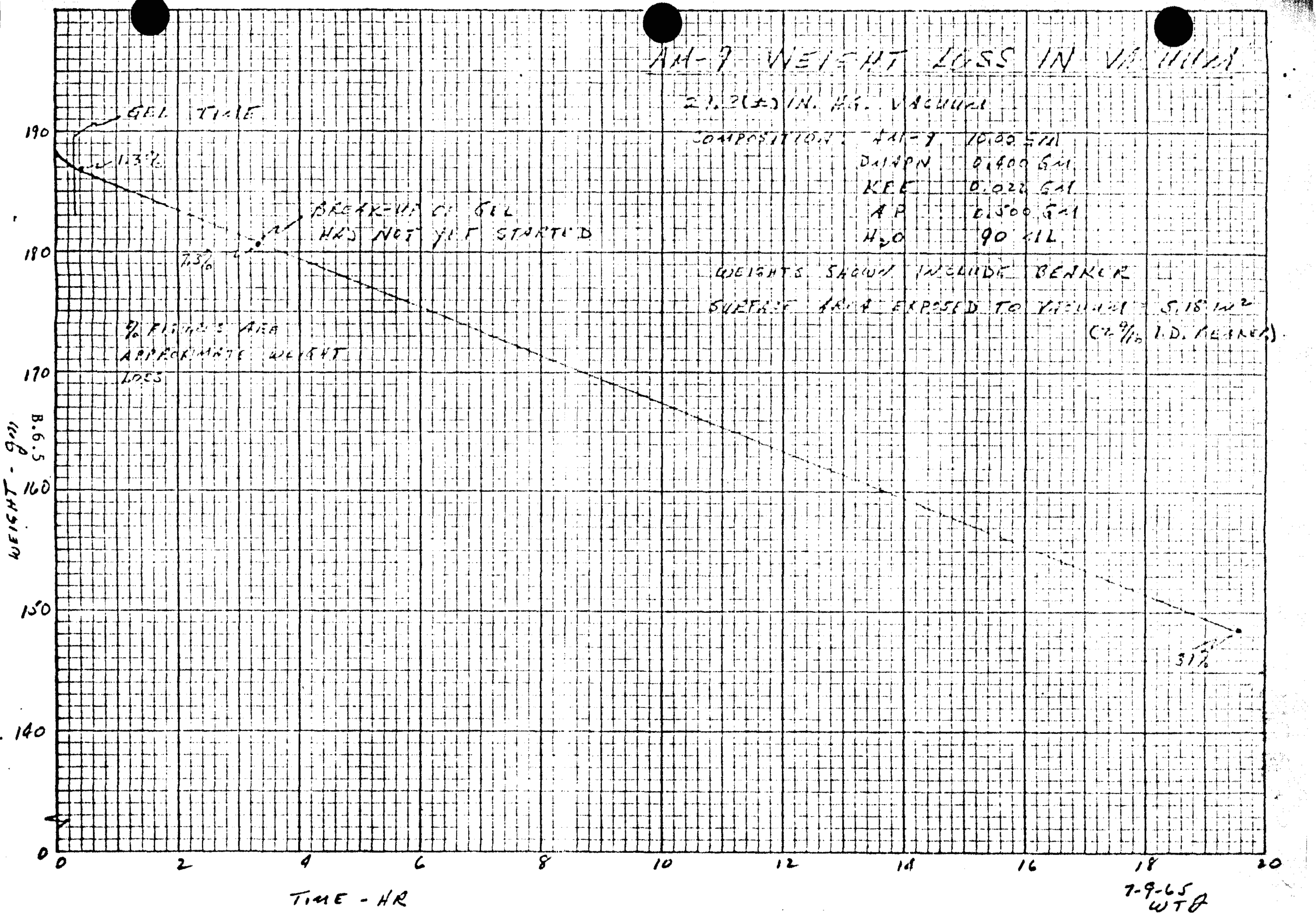
The only problem here seems to be the material selection. This concept fits very closely within the framework of this investigation which so far has revealed no suitable material for overburden consolidation.

<u>CONCLUSIONS</u>:

1. Consolidation by freezing the area sround the drilling site is not practical because of the heat transfer problems and the difficulty in selecting a fluid to use in the lunar environment.

2. Consolidation by chemical means is not practical.

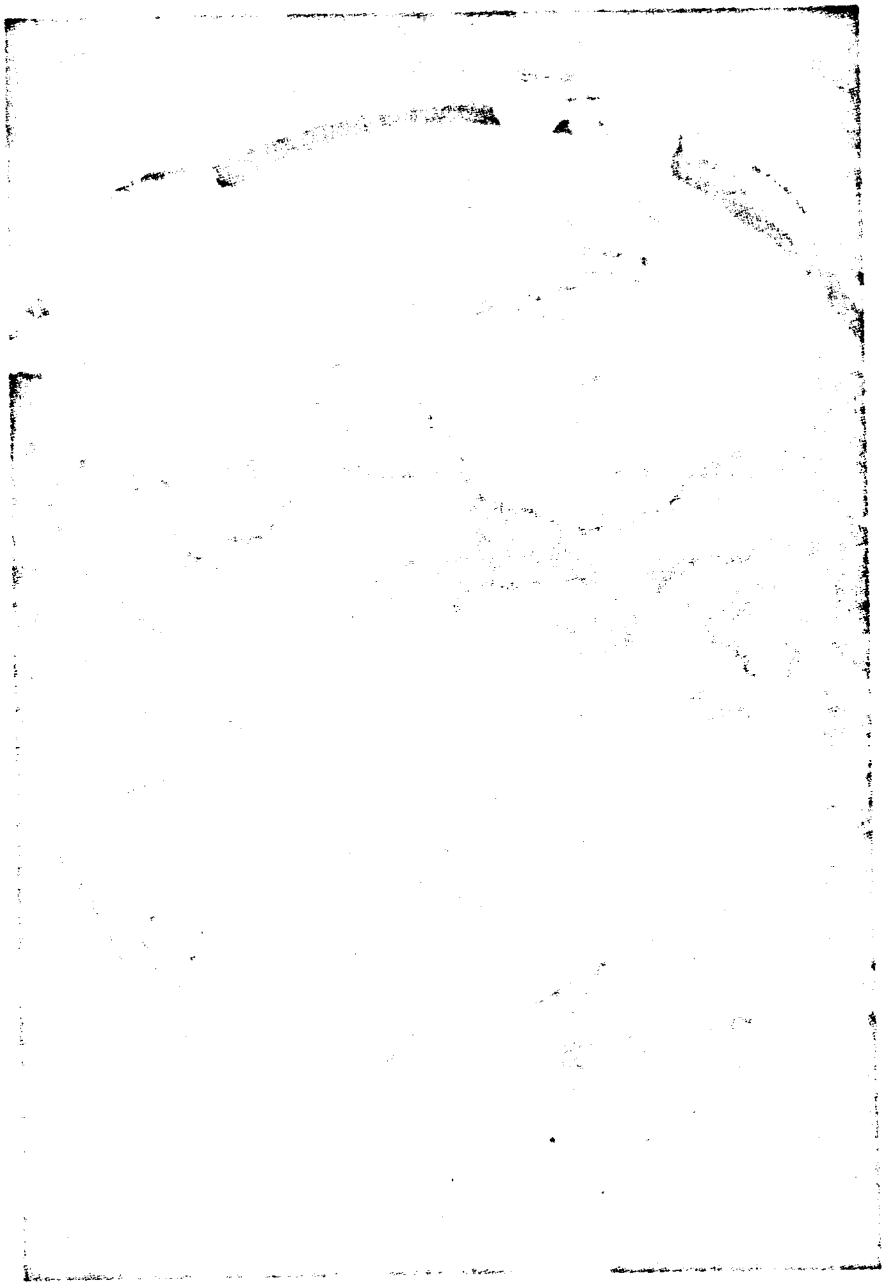
3. Consolidation by chemical grout or resin might be possible. However, to develop this concept any further would take a considerable material development program. Such a program is beyond the scope of this investigation.



AH-7 WEIGHT LOSS IN VACUUM
21.3(±) IN. HG. VACUUM
COMPOSITION: AH-7 10.00 GM
DAIAPN 0.400 GM
KEE 0.022 GM
AP 0.500 GM
H_2O 90 ML
WEIGHTS SHOWN INCLUDE BEAKER
SURFACE AREA EXPOSED TO VACUUM = 5.18 IN^2
(2 9/16 I.D. BEAKER)
GEL TIME
1.3%
BREAK-UP OF GEL HAS NOT YET STARTED
7.3%
% FIGURES ARE APPROXIMATE WEIGHT LOSS
31%
190
180
170
160
150
140
0
0
2
4
6
8
10
12
14
16
18
20
TIME - HR
WEIGHT - gm
7-9-65
WTO

B.6.5

FIGURE 1



BREAK-UP OF AM-9 GEL AFTER
19-1/2 HR EXPOSURE TO VACUUM

FIGURE 2

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CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 5-4-65 BY: TNW

DESCRIPTION: CONSOLIDATE DUST AROUND DRILLING SITE BY FREEZING OR CHEMICAL MEANS OR GROUTING.

SKETCH: NONE

ADVANTAGES: ELIMINATES PROBLEM OF SEALING DUST OUT OF SYSTEM.

DISADVANTAGES: ① POSSIBLE INTERACTION BETWEEN CHEMICALS OR WATER AND THE SAMPLE. ② POSSIBLE WEIGHT PENALTY DEPENDING ON THE SYSTEM. ③ SOLIDIFICATION BEFORE DRILLING MAKES AN EASILY NEGOTIATED OVERBURDEN DIFFICULT

DISPOSITION:

CONCEPT NO. 10

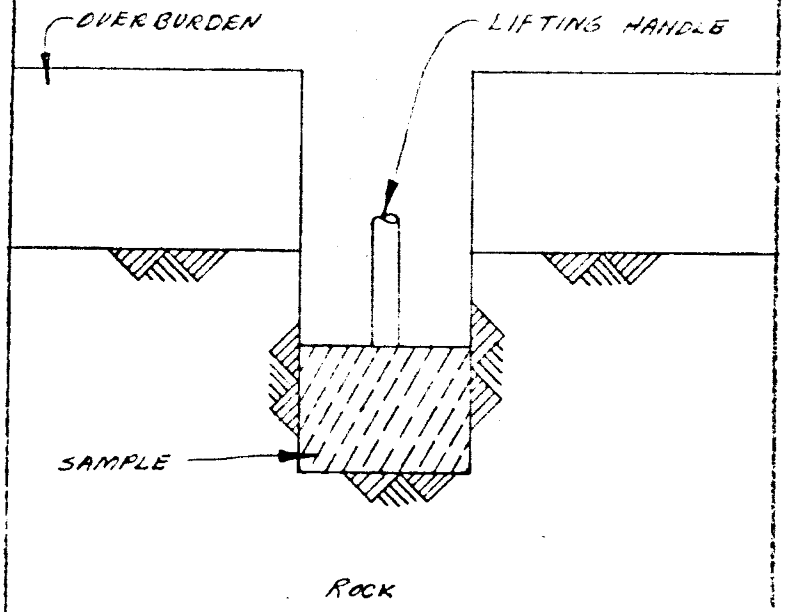
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 5-20-65 BY: M. M.

DESCRIPTION: POPSICLE IDEA. PUT A GLOB OF MATERIAL DOWN IN A HOLE CONTAINING DUST. SOLIDIFY MATERIAL AND ENTRAP SAMPLE AND A LIFTING HANDLE. BRING UP TO SURFACE, LIQUIFY MATERIAL, AND SEPARATE SAMPLE.

SKETCH:



ADVANTAGES: ESSENTIALLY A MECHANICAL TRANSPORT SYSTEM.

DISADVANTAGES: ① MATERIAL SELECTION IS A PROBLEM BECAUSE OF LUNAR ENVIRONMENT. ② IF ROCK IS POROUS, — OR NO ROCK IS ENCOUNTERED, ONLY POROUS (INTERCONNECTED) OVERBURDEN — MATERIAL GOES INTO ROCK OR OVERBURDEN AND AN IMMOVABLE PLUG HAS BEEN CEMENTED IN BOTTOM OF HOLE.

DISPOSITION:

CONCEPT NO. 10 A

APPENDIX B.7

REPORT OF INVESTIGATION

REMOVAL OF OVERBURDEN BY ELECTROSTATIC REPULSION

INTRODUCTION:

This report covers the investigation of Concept 11 which states "Use electrostatic repulsion to move dust away from drill site". This concept was advanced as a result of the statement by Kopal [1] referring to the effect of the solar wind: "All three processes ... are bound to keep charging the surface of the Moon positively in the course of time..."

INVESTIGATION:

The first step in this investigation was to conduct a literature search in an effort to determine the amount of charge on the particles. Vey and Nelson [2] say that Gold [3] and Grannis [4] have attributed a considerable amount of lunar erosion to solar radiation. They also make the statement that attractive and repulsive surface forces between soil particles may be developed under ultra-high vacuum.

Salisbury [5] sifted basalt powder in a vacuum chamber. This powder built up on fine wires in the chamber as well as on the chamber walls. He found that the particles were electrostatically charged. Some particles had plus charges, others had minus charges, and there were groups of particles that together were neutral. He also made the statement, "But with particles of both signs, as well as neutral groups, even if you charge a plate you will always get particles adhering to it".

Grannis [4] has used a statistical approach to calculating the upper limit on the charge of a grain of 5μ silica dust on the Moon's surface due to the effect of the solar wind. He found the upper limit to be $\pm 2800e$, where e is the electron charge. He then discusses electrostatic hopping and develops an equation for the rate of downhill mass transport due to this hopping.

Walker [6] carries the calculations a little further by including the effect of the change in rate of charge build-up on a grain as the grain charge becomes larger. He says that 2800e is too high and concludes that the statistical fluctuation of charge on the lunar dust grains is not significant. He also states that in an independent investigation by Singer and Walker it was found that electrostatic forces were insufficient to tear loose dust particles, or even to raise them.

Coffman [7] calculates the charge on a grain of dust using energy methods. He finds that the maximum number of electrons which can be attached to a 5μ grain of dust is 7600. His discussion of the critical radius for hopping follows:

> "Hopping of dust grains will occur in an electric field. However, there is a critical radius which limits the size of the grains which hop. The maximum charge (maximum number of electrons) is proportional to the radius of the grain. Thus, the maximum electric force on the grain is proportional to its radius. But the gravitational forces, for a grain of uniform mass density, is proportional to the cube of the radius. It follows that the curves representing the magnitude of the gravitational force (which is attractive) and the magnitude of the electric force (which is repulsive) will intersect for some radius $a > 0$, which is the critical radius. Grains of larger radius cannot acquire a charge large enough to lift them against the gravitational field... The critical radius for grains of sand on the moon cannot be calculated because the electric field intensity at the surface of the moon is unknown".

To further complicate the situation, Mitchell [8] says, "Continual radiation bombardment of the Moon's surface could cause sputtering of ions which could redeposit between particles. Laboratory experiments... showed that a brittle crust of particles cemented together by atoms sputtered back and forth in spaces between grains could be formed."

Wehner [9] speculates on the effects of solar wind bombardment of the lunar surface for 10^9 years. Under this bombardment, sputtering occurs, the larger portion of the sputtered material escapes the Moon's gravitational attraction and is lost into space. However, on rough surfaces a considerable number of atoms may be trapped again after sputtering. As a consequence,

> "atoms which are sputtered and then subsequently trapped provide the glue which cold fuses surface particles together or surface particles to underlying particles. Thus, we may reasonably expect that the lunar surface does not consist of a loose dust layer but is rather a porous but relatively solid crust of fused dust particles".

Experiments by Wehner et al [10, 11] have shown that in simulated solar wind bombardment such a crust is formed on layers of steel spheres, layers of metal powders, various oxide powders, and various rock powders. Their description of the crust and their conclusions follow.

"Whenever a crust is formed it has a fibrous structure with closely spaced needles & spires & deep small holes all aligned in the dirction of ion bombardment... At the Moon, the conditions are different because the bombardment sweeps the surface over a range of angles. This should cause the surface to become more complex and irregular, but it probably would not change its basic character. This layer is probably not contradictory to the "fairy castle" structure proposed by Hapke [12] or the "skeletal fuzz" proposed by Warren [13]for explaining the photometric properties of the lunar surface".

At this point itbecame apparent that no design criteria could be developed for a system to electrostatically repel the dust from the drill site. In fact, according to Wehner, there may not be any dust on the surface but a brittle crust which would have to be broken in order to get down to the dust. Therefore, the investigation was terminated.

CONCLUSIONS:

(1) Although Kopal [1] and Gold [3] say dust particles on the Moon's surface will all be positively charged, Grannis [4], by considering solar proton bombardment, solar electron bombardment, secondary and photoelectric emission, and the return of electrons to the surface to be independent processes, finds statistically that a grain can be positively or negatively charged. Vey and Nelson [2] and Salisbury [5] find that both positive and negative charges build up on dust particles in high vacuum on earth. If indeed the lunar dust has both positive and negative charges, then any type of electrostatic repulsion mechanism will be useless; it will attract just as many particles as it repels.

(2) Grannis [4], Walker [5], and Coffman [6] all disagree on the maximum possible charge which could develop on the lunar dust. Hence even if the dust particles were all positively charged, the amount of charge to use as a design criterion is undetermined.

(3) Theoretical and experimental work by Wehner, [9, 10, 11] strongly suggests the existence of a crust on the lunar surface. Any mechanism used to get thru the curst could just as well be used to get thru the underlying dust without the necessity for electrostatic repulsion.

(4) No further work should be expended on this concept because of the three preceding conclusions.

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CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 5-4-65 BY: TWW

DESCRIPTION: USE ELECTRO-STATIC REPULSION TO MOVE DUST AWAY FROM DRILL SITE.

SKETCH: NONE

ADVANTAGES:

DISADVANTAGES: ① WEIGHT AND SIZE OF EQUIPMENT NECESSARY TO MOVE DUST. ② WILL NOT WORK ON RUBBLE WITH REASONABLE EQUIPMENT SIZE. ③ WHAT IS THE CHARGE OF THE OVER-BURDEN? REQUIRES SOME PRE-KNOWLEDGE - PROBABLY UNATTAINABLE.

DISPOSITION:

CONCEPT NO. 11

APPENDIX B.8

REPORT OF INVESTIGATION

REMOVAL OF OVERBURDEN

Introduction:

This report covers the investigation of Concepts 12, 12A, 13, 14, and 15. Concept 11 which also has to do with removal of overburden is discussed in a separate report.

Investigation:

Concept 14 was immediately ruled out as a complete system since it would not work on a cohesive overburden. However, its use in combination with some other system was not discounted.

Concepts 12, 13 and 15 are all mechanical methods. Therefore before evaluating them as such it was decided to first evaluate mechanical methods in general, then move on to specifics. In general two types of motion are available to move the overburden: 1) Scraping, in which a blade or bucket is moved essentially parallel to the overburden surface and 2) Rotating, in which a wheel or chain is rotated about an axis parallel to the overburden surface and buckets or blades on the periphery of the wheel move the overburden.

Scraping can be accomplished in three ways:

1) A bucket or blade is thrown out and scraping accomplished as it is pulled back in. Draglines, back-hoes, and Concept 15, the Hughes Aircraft Surface Sampler, operate in this manner.

2) A bucket or blade scrapes as it is pushed away, then it is retracted for another scraping stroke. Power shovels used in strip mines on earth and bulldozers operate essentially in this manner.

3) A blade can be rotated in an arc about an axis perpendicular to the overburden surface in a manner similar to a windshield wiper.

A dragline mechanism would require a boom, cables, clutches, brakes, and a vertical axis about which to pivot. The coordination of the controls necessary to operate such a system, the complexity of the system, and the possibility that it would not work in a cohesive overburden make such a system unsuitable. Back-hoes have many advantages when compared to draglines. However, they require an extensive hydraulic system which would present innumerable problems in a vacuum (1). Therefore the back-hoe mechanism was discarded.

Concept 15 has already been developed by Hughes Aircraft; the idea was thrown into the brain storming sessions to see if it would generate any other ideas. For this reason no further consideration was given to Concept 15.

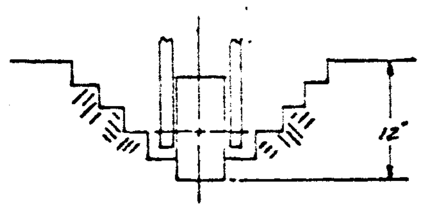
Power shovels as used in strip mines on earth are efficient mechanisms for overburden removal. However, their efficiency is due to their large size, and just as the draglines, they require coordination of controls to operate. Booms, cables, clutches, brakes, and a trundle are required. A mechanism somewhat simpler than the usual cable operated power shovel is shown in Figure 1. (2). However the gear teeth and pin joints would all be exposed to the vacuum on the lunar surface and would be a lubrication problem. The mechanism to vertically move the mechanism shown would add to the complexity, therefore this concept was discarded. A bulldozer type blade was considered, but no simple mechanism could be devised to impart both horizontal and vertical motion as well as brute force to the blade. A miniature radio controlled dozer was considered. However, its small weight would limit its pushing power and it probably could not break up a cohesive crust. If the crust is not cohesive, then the dozer would have locomotion problems. Any rock sampling mechanism would be in addition to this complex system. Therefore this idea was discarded.

The windshield wiper concept was ruled out because of the high torque necessary at the vertical axis to clear an area large enough to accomodate a sampling mechanism. At this point all the scraping mechanisms had been eliminated.

To begin thinking about the rotating mechanisms, it was necessary to get some idea of the angle of repose of a loose dust on the lunar surface. Sibulkin (3) found the upper limit angle of repose of cork, ground walnut shells, sand, and copper to be between 35^o and 40^o. He also found that the sides of a hole eroded in a layer of these dusts by a vertical blast of air had a maximum slope of about 40^o. All of his work was done in an initial vacuum of 10^{-5} Torr. The actions of particles of lower mass, such as cork and walnut shells, in the earth's gravity field would correspond to the actions of particles of higher mass, such as rock, in the lower lunar gravity field. Vey and Nelson (4) found the internal friction of silica flour to have a value of tan ϕ =0.70 at 10^{-9} Torr. This corresponds to an angle of repose of ϕ =35^o. Therefore for concept thinking purposes it was assumed that a loose dust on the lunar surface would have an angle of repose of $35\text{-}40^o$.

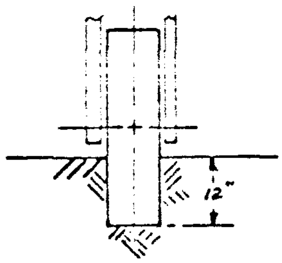
The next decision to be made was the size and shape of the rotating member. The following possibilities exist:

1) Small diameter - no problems with mounting if overburden is non-cohesive. If overburden is cohesive the following cross section will have to be cut in order to clear the wheel support and drive members.



Thus movement in three mutually perpendicular directions will be required.

2) Large diameter. This requires a heavier wheel, but movement is required only in two directions, vertically and one direction horizontally.



3) Wide. A large area could be cleared by movement in only one horizontal direction. However, the power required would be high. Tests by the Joy Manufacturing Company (5) on different methods of mine emplacement showed that a drum (35" dia. x 18" long) rotating about a horizontal axis would excavate a well formed 12" deep hole in various earth soils in a short time. However, compared to conventional methods, such as augering, excessive power was required.

4) Narrow. This would in effect, cut a trench through the overburden, but the power requirements would be lower.

Concept 13 overcomes the difficulties associated with 2) above. However, there is a lubrication problem for each link in the chain. In addition, a chain with drag cutters mounted on it did not produce a clean hole in all soil conditions in the Joy Manufacturing Company tests (5). One solution is to use a one-piece "chain" such as a steel belt. The mechanism then would be that of a belt sander. However, problems still exist such as cutting the sides of a trench in a cohesive formation, keeping the belts in setting up the equations, particularly the assumption of only a single particle, did not seem to make the numerical solution of the problem worth the effort. An answer could have been obtained using numerical methods and the 1410 computer but the answers probably would not have any relation to the physical situation. Experimental work with a breadboard model in a vacuum would give more reliable answers. Therefore for concept purposes a sample catcher with its own vertical drive system rather than deflector will be used. If it is decided to build a breadboard model based on this overall concept, the addition of a deflector for testing will be a simple matter.

At this point the complete system was envisioned as:

1. A large diameter, narrow, overburden wheel with a drive system to supply rotation.
2. A feed mechanism to move the overburden wheel horizontally in the plane of rotation.
3. A vertical feed mechanism.
4. An air blast to clean the rock surfaces of any loose particles before sampling.
5. A sample wheel and drive system.
6. A sample catcher.

Two concepts for meeting these requirements are shown in Figures 2, 3, and 4. Figure 2 is a combination overburden wheel and sample wheel with a method of mechanically entrapping the sample. Figure 3 shows the detail of the wheel of Figure 2. The support structure supports the motor on one side and a pressurizing air system on the other side as well as providing a journal support for the rotating wheel. The rotating portion of the wheel has a T-shaped cross section with a ring gear on its inside diameter. This allows the wheel to be rotated thru the idler and pinion arrangement shown. The rotating portion is a multiple part assembly consisting of an outer over-burden wheel and an inner sample wheel. The sample wheel has a grinding surface on its outer diameter. The overburden wheel is fastened to the sample wheel in sections with explosive bolts. The overburden wheel is essentially a staggered tooth side milling cutter. Each tooth extends only half the width of the wheel so that the cutting load on each tooth is reduced. The teeth are alternately placed on different sides of the wheel center line so that the entire width of the trench being cut is covered.

The overall concept is shown in Figure 3. The wheel of Figure 2 is shown mounted so that it can be moved vertically or horizontally in the plane of the paper. A deflector and sample tray with its own vertical drive are shown mounted on the same horizontal lead screw and support tube as the wheel. The sequence of operation is as follows:

1. The wheel is lowered and a trench is cut in the overburden down to rock using the milling cutter teeth.
2. The explosive bolts are fired and the sections of overburden wheel fall off exposing the grinding surface of the sample wheel.
3. The deflector is lowered into the trench and the air supply mounted on the deflector directs a blast of air (or gas) at the exposed rock thereby removing the last particles of overburden.
4. The sample wheel is rotated and the rock particles are deflected into the tray.

An incomplete variation of this system is shown in Figure 4. The wheel detail is shown on the left. Here the rotating portion is a one-piece staggered tooth side mill. On the right is shown a portion of the overall concept; that part not shown is very similar to Figure 3. Here the sampling wheel is the Litton Industries small "vacuum cleaner" (6) of concept 12A. The sequence of operation is as follows:

1. The overburden wheel is lowered and a trench is cut thru the overburden.
2. The "vacuum cleaner" is lowered into the trench. The bellows provides a seal on the hardpan. Air is supplied to the air turbine which rotates the grinding wheel. Exhaust air from the turbine picks up the sample particles and transports them up thru the support tube to the surface.

<u>Conclusions</u>

1. The removal of overburden concept is feasible.
2. Two possible configurations are shown in Figures 2, 3, and 4.
3. Problem areas still exist in these configurations; some of these are:
    a) overall complexity - three motors, two lead screws, etc.
    b) overburden wheel removal in Figure 3
    c) seal between box and rock in Figure 4
4. The configuration shown in Figure 3 can take an uncontaminated sample of rock or of overburden, but not both.

5. The configuration shown in Figure 4 can take an uncontaminated sample of overburden, rock, or both by the addition of valving and cyclone separators at the exhaust end of the air transport system. However, lost circulation is possible if no solid rock is encountered.

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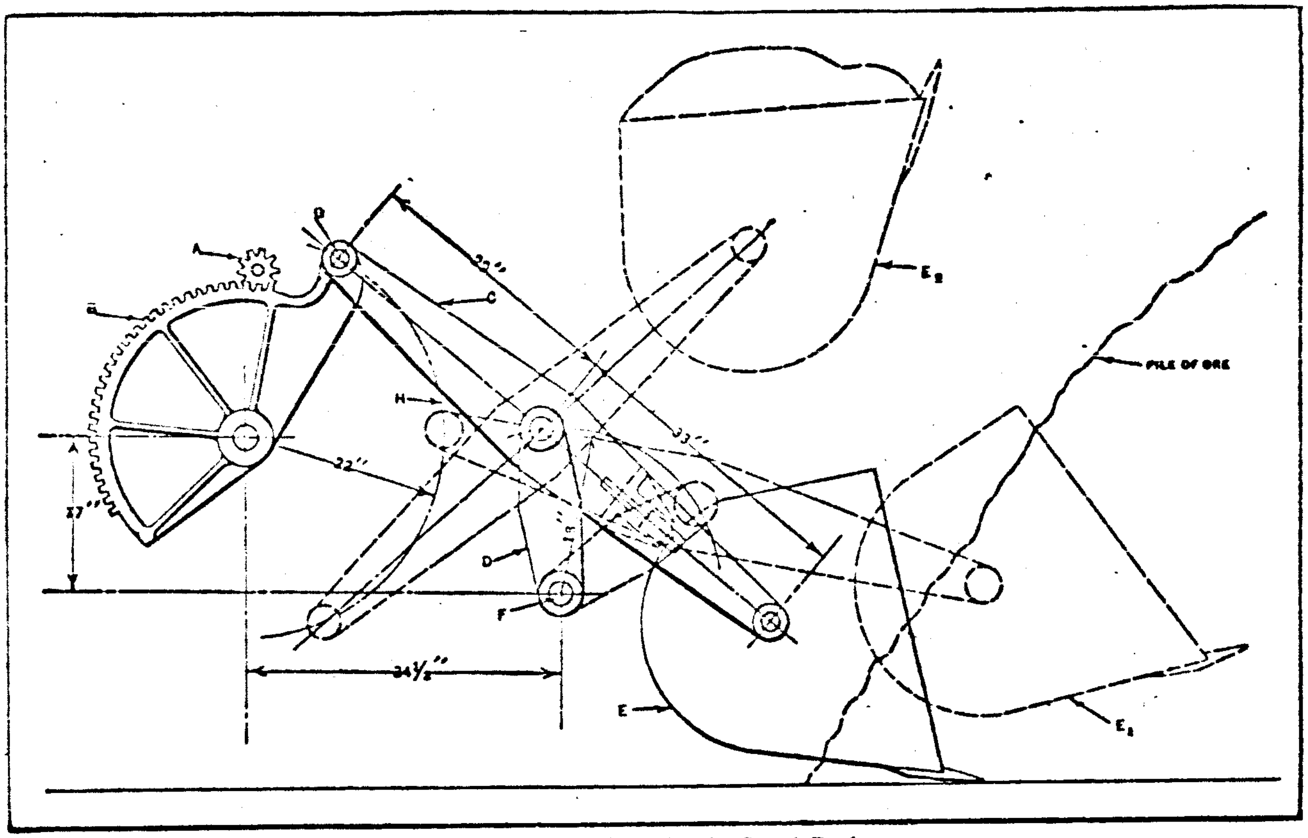
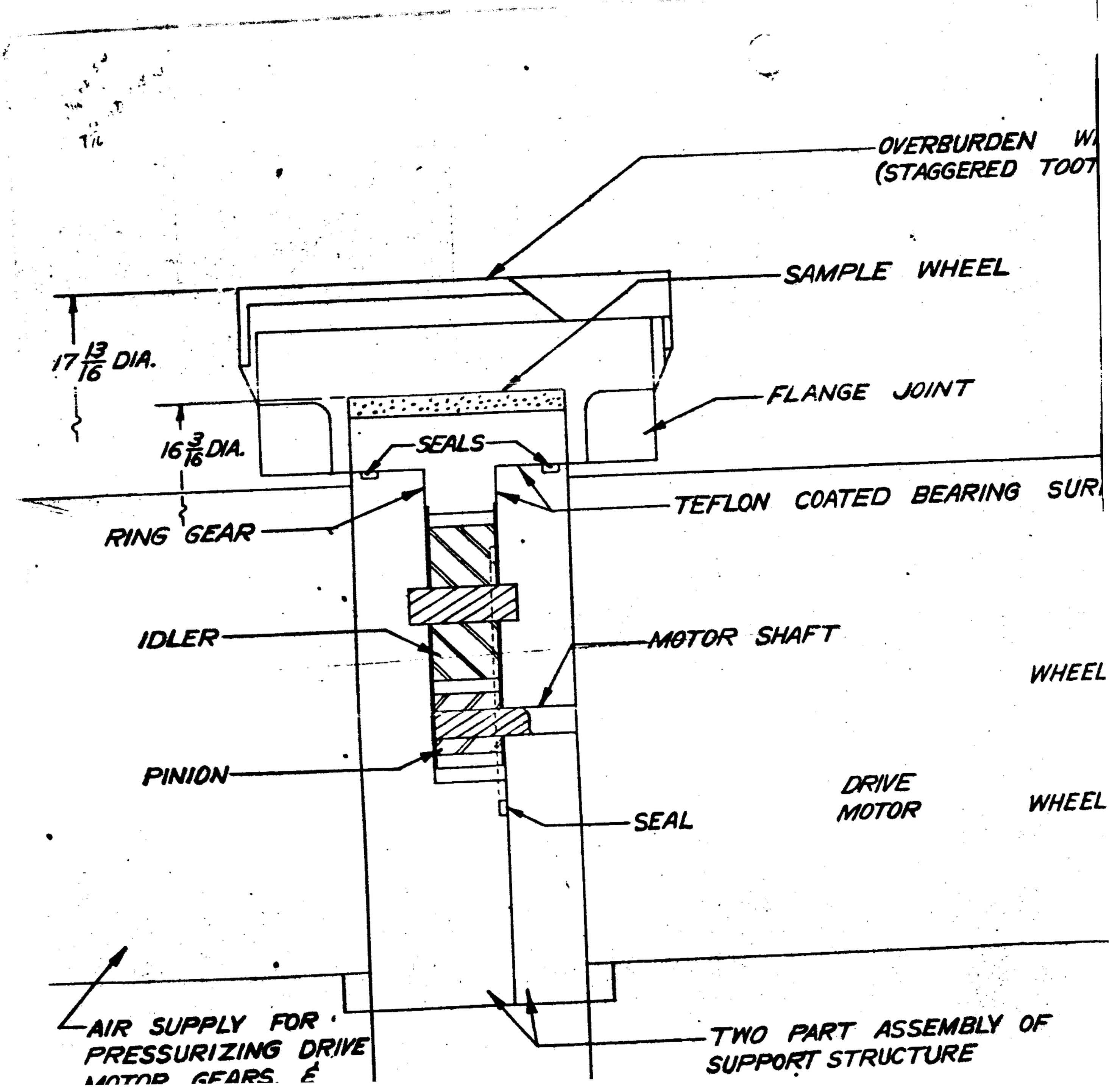
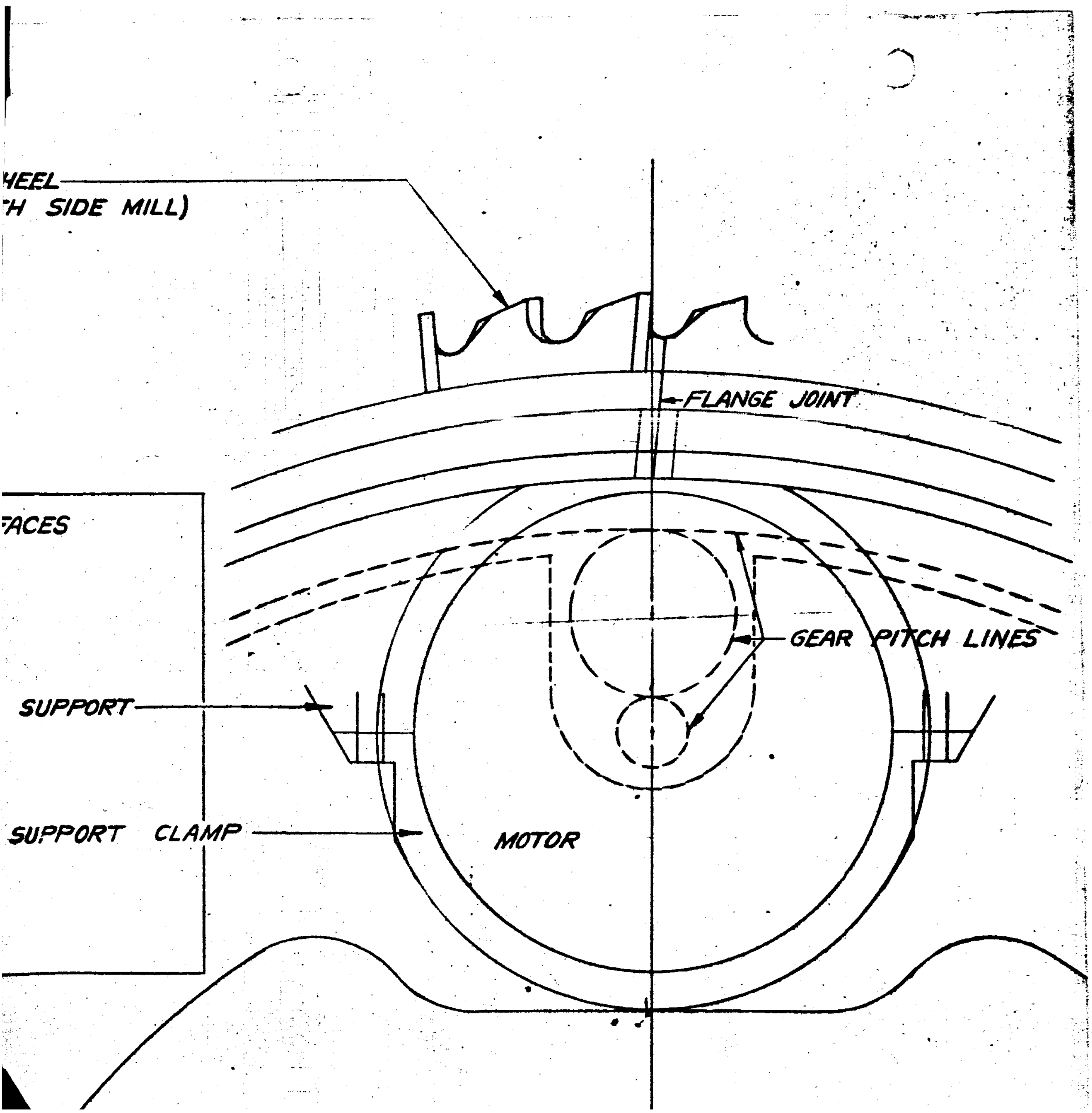


Fig. 1 Scooping Mechanism for Shovel Truck

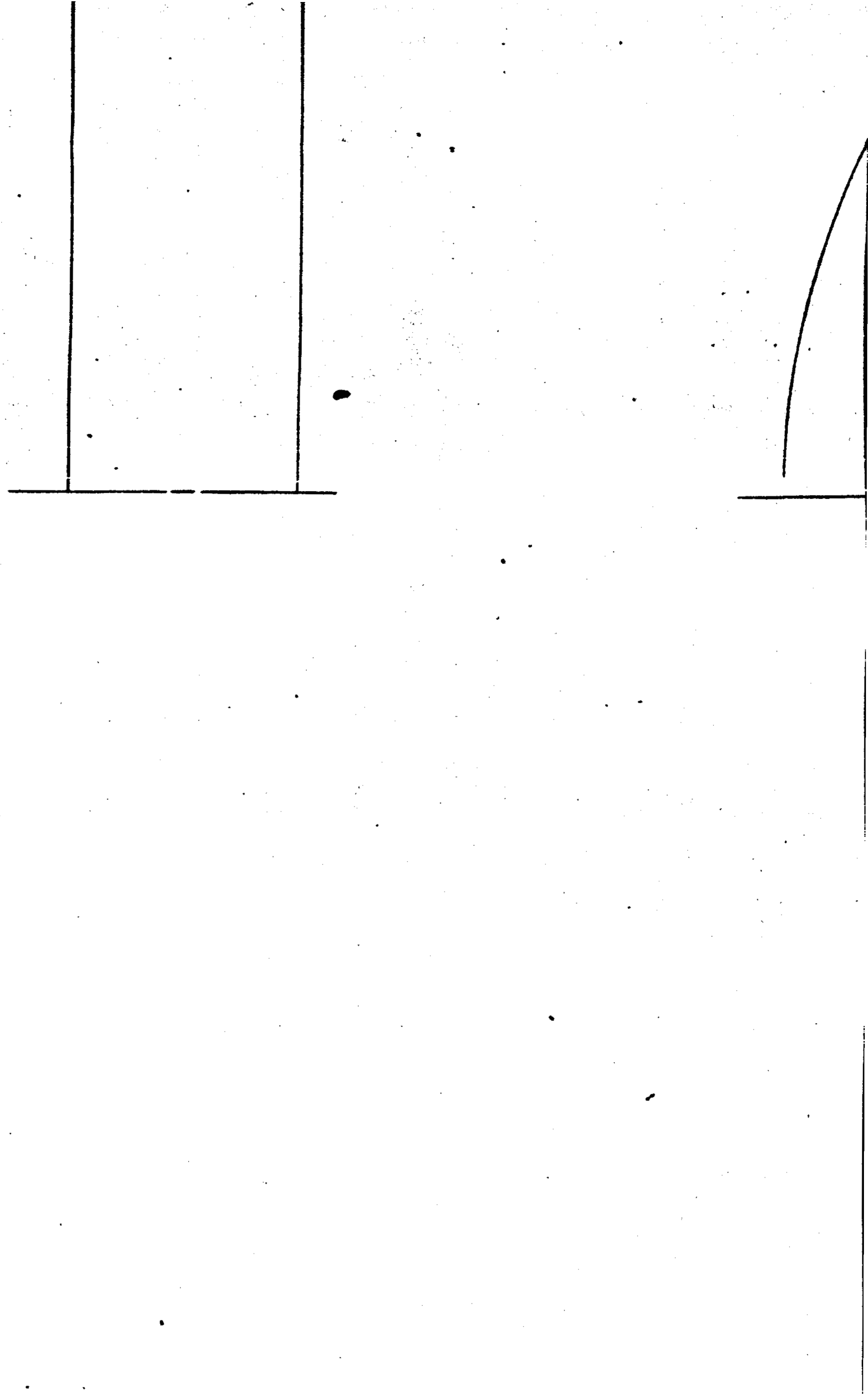
TOP I


OVERBURDEN W
(STAGGERED TOOT
SAMPLE WHEEL
17 13/16 DIA.
16 3/16 DIA.
FLANGE JOINT
SEALS
TEFLON COATED BEARING SUR
RING GEAR
IDLER
MOTOR SHAFT
WHEEL
PINION
DRIVE MOTOR
WHEEL
SEAL
AIR SUPPLY FOR PRESSURIZING DRIVE MOTOR GEARS &
TWO PART ASSEMBLY OF SUPPORT STRUCTURE

2

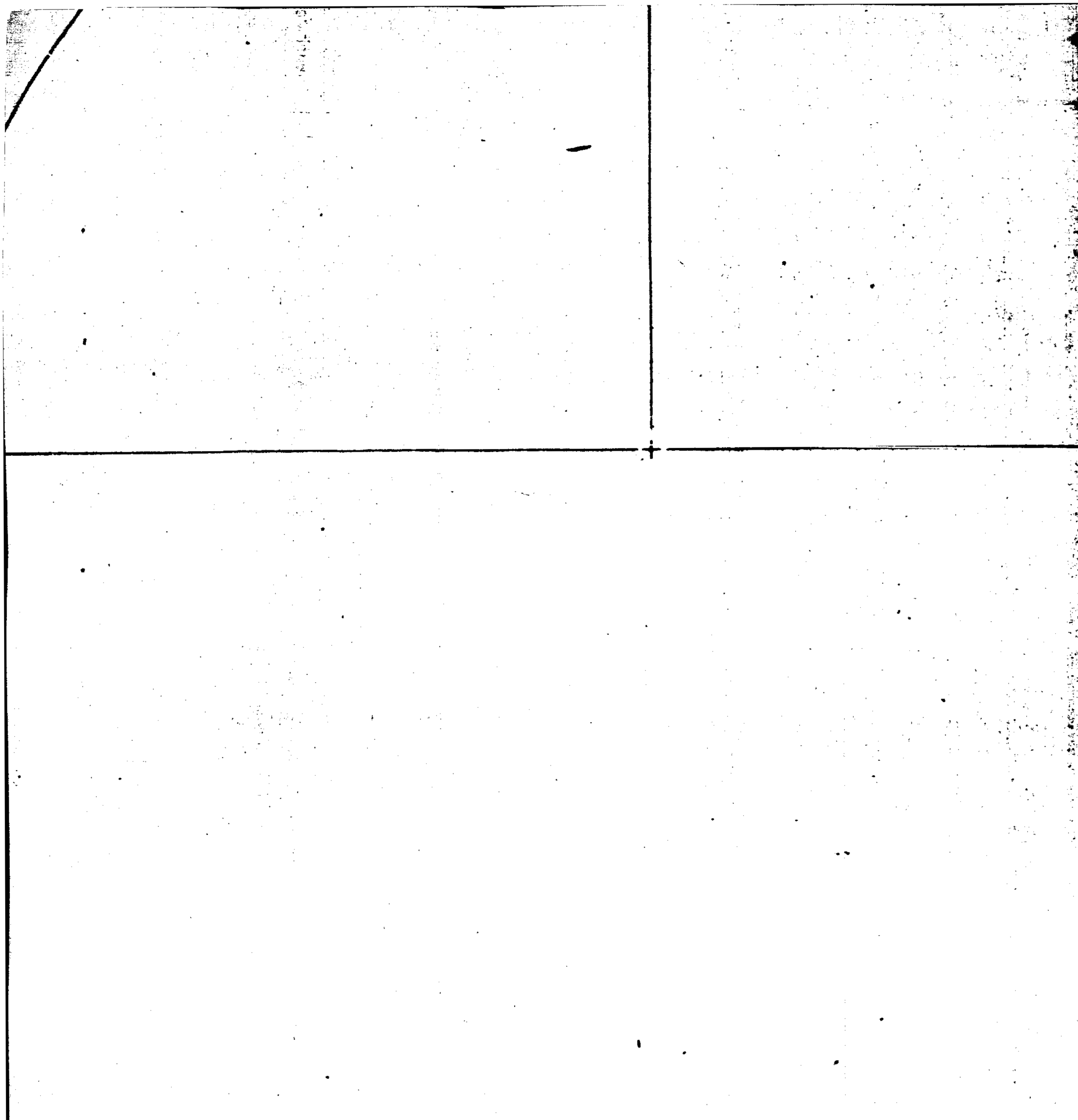

HEEL
H SIDE MILL)
FLANGE JOINT
FACES
GEAR PITCH LINES
SUPPORT
SUPPORT CLAMP
MOTOR

(IF NECESSARY)



BOTTOM 3

161



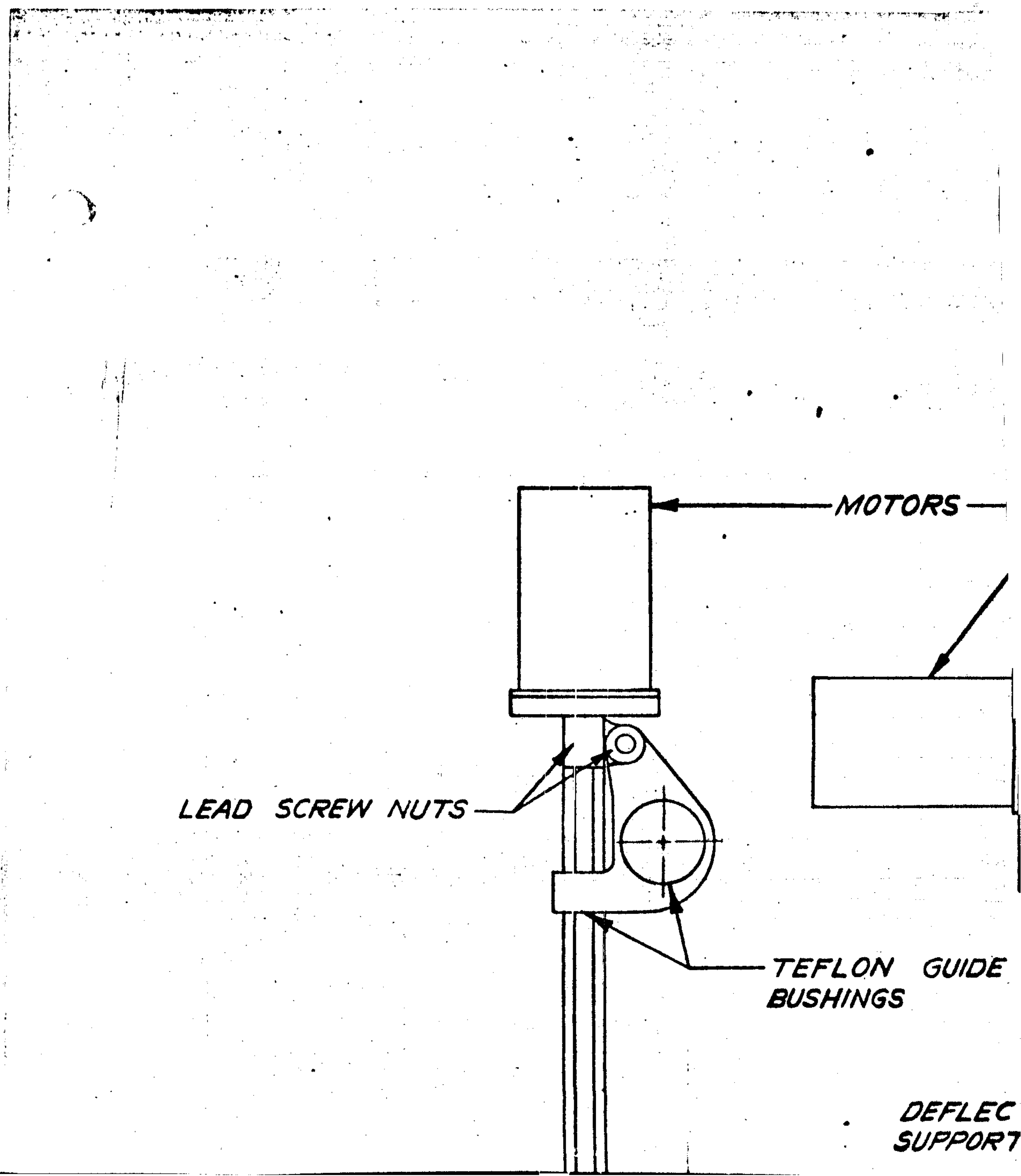
WHEEL DETAIL

45 30 0037

WTJ FULL SCALE 6-28-65

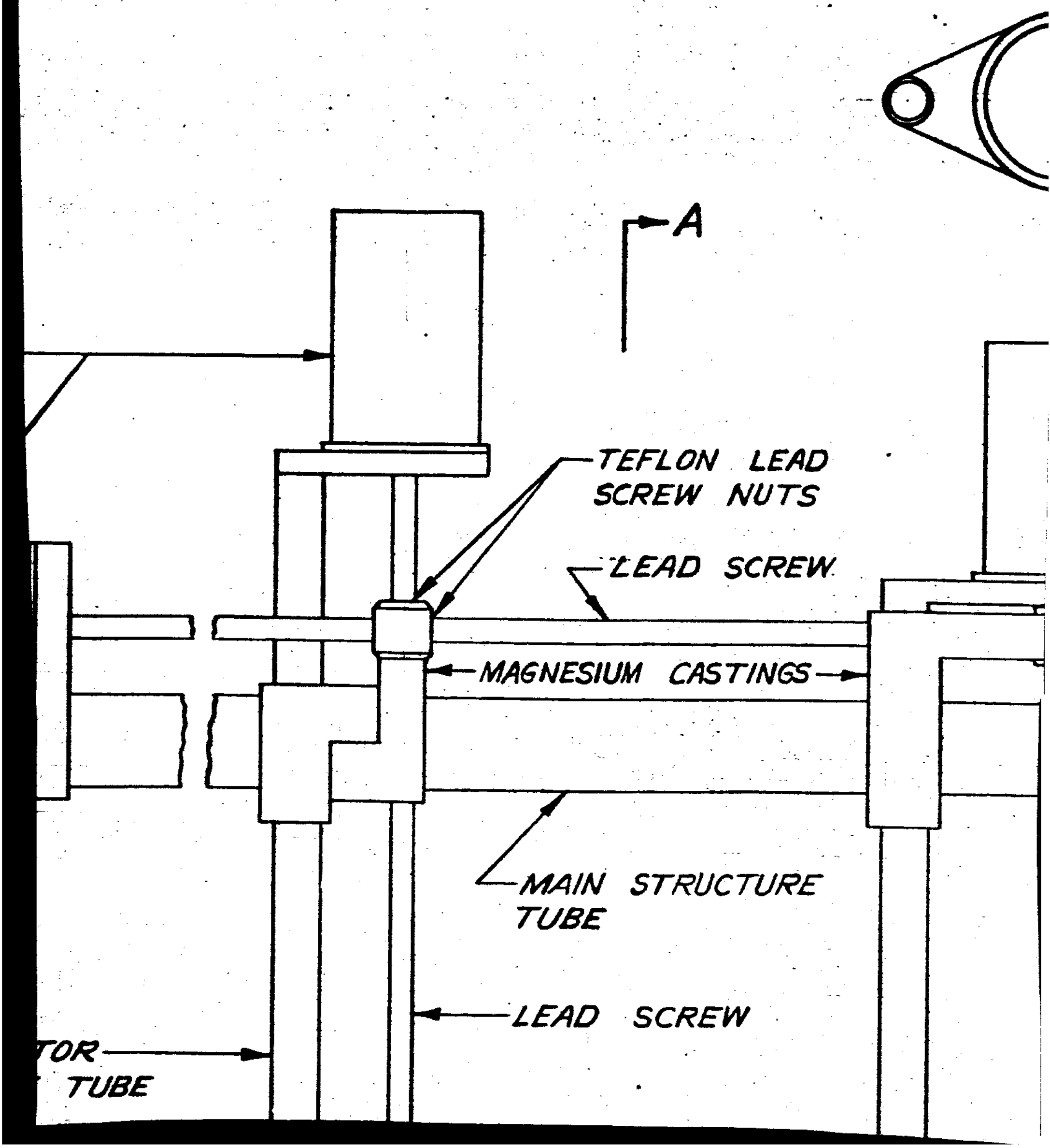
FIGURE 2

TOP 1



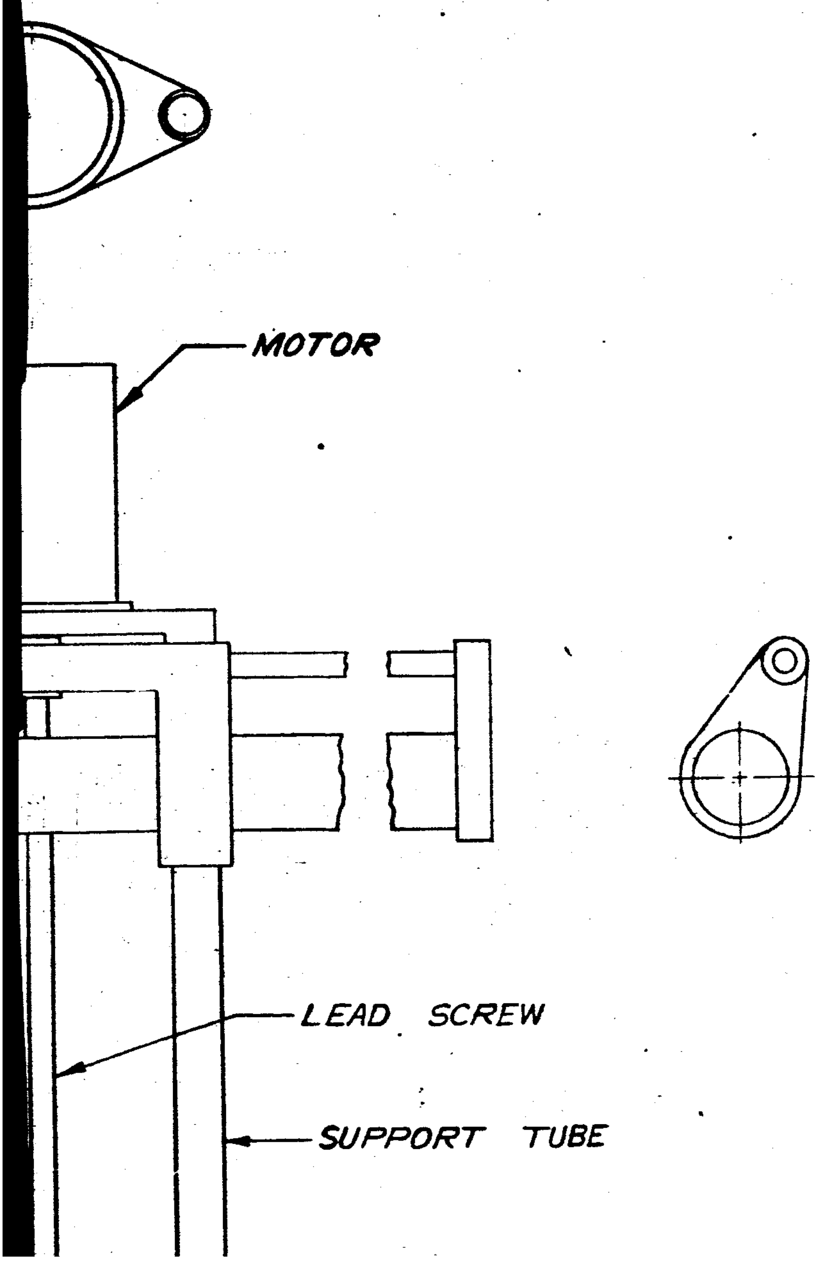
MOTORS
LEAD SCREW NUTS
TEFLON GUIDE BUSHINGS
DEFLEC
SUPPORT

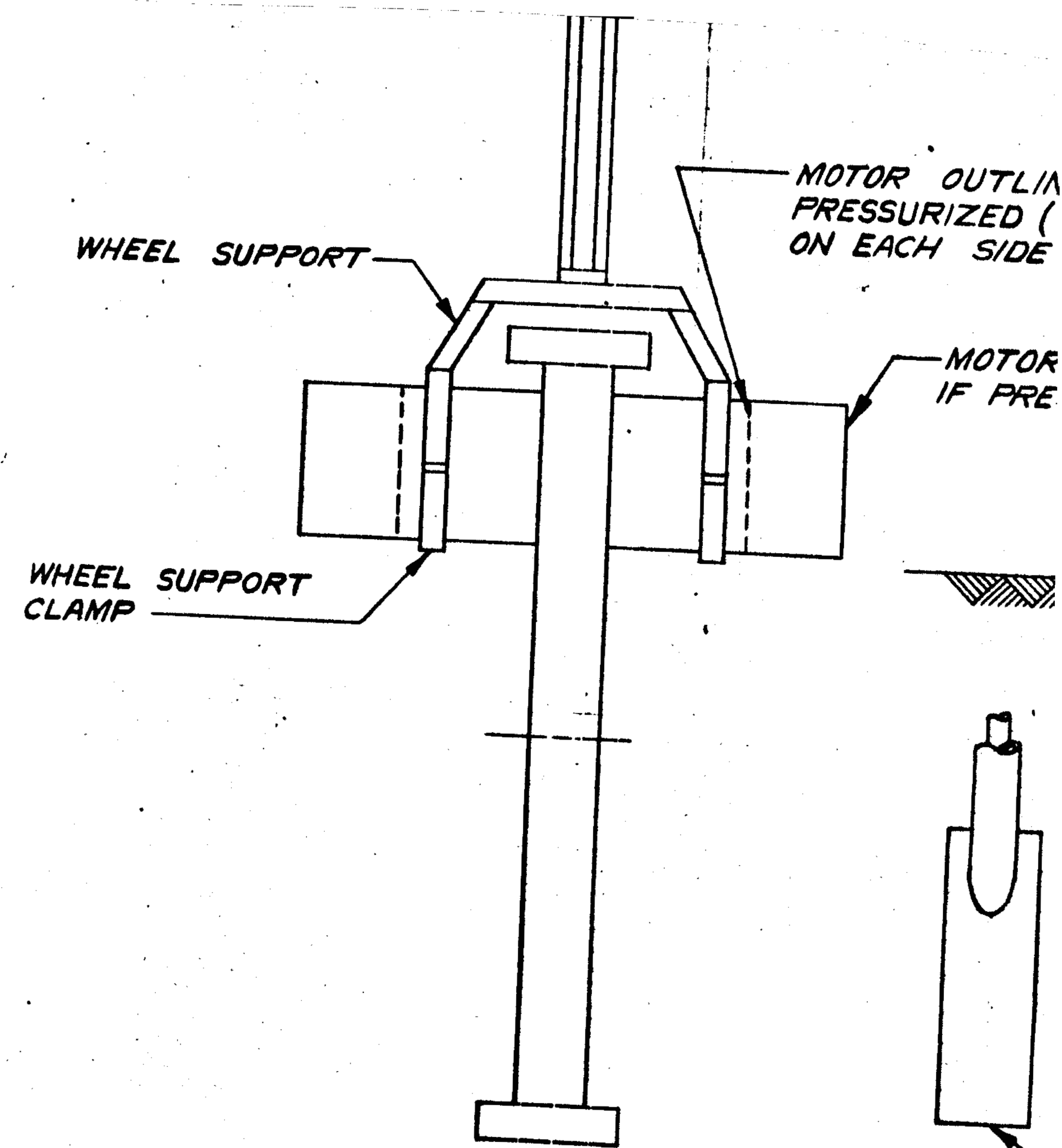
2


A
TEFLON LEAD
SCREW NUTS
LEAD SCREW
MAGNESIUM CASTINGS
MAIN STRUCTURE
TUBE
LEAD SCREW
TOR
TUBE

3

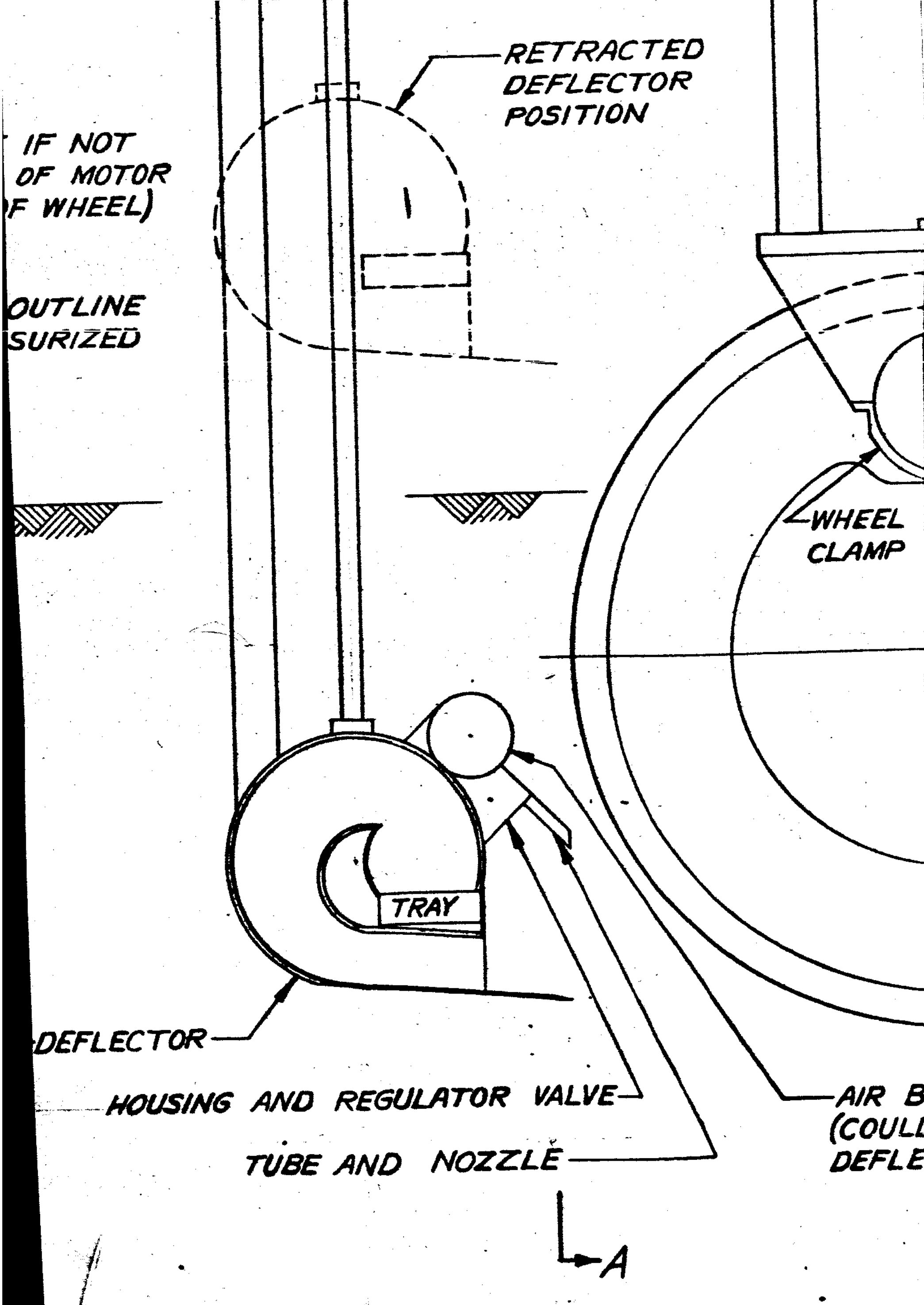
RE-ORDER No. 65-757

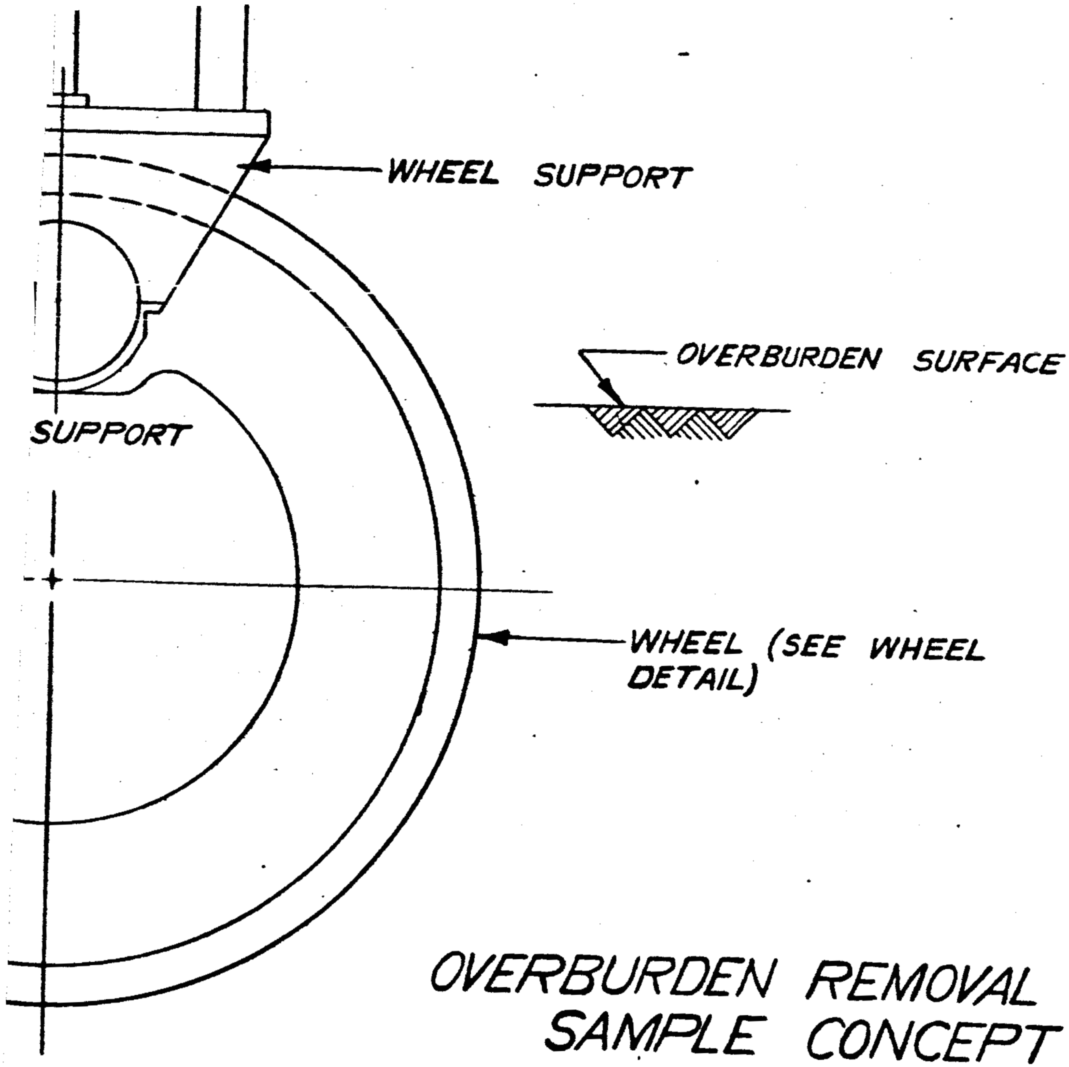




VIEW A-A

BOTTOM 4


RETRACTED
DEFLECTOR
POSITION
IF NOT
OF MOTOR
F WHEEL)
OUTLINE
SURIZED
WHEEL
CLAMP
TRAY
DEFLECTOR
HOUSING AND REGULATOR VALVE
TUBE AND NOZZLE
AIR B
(COULL
DEFLE
A
5



162

OVERBURDEN REMOVAL AND SAMPLE CONCEPT

45 30 003 7

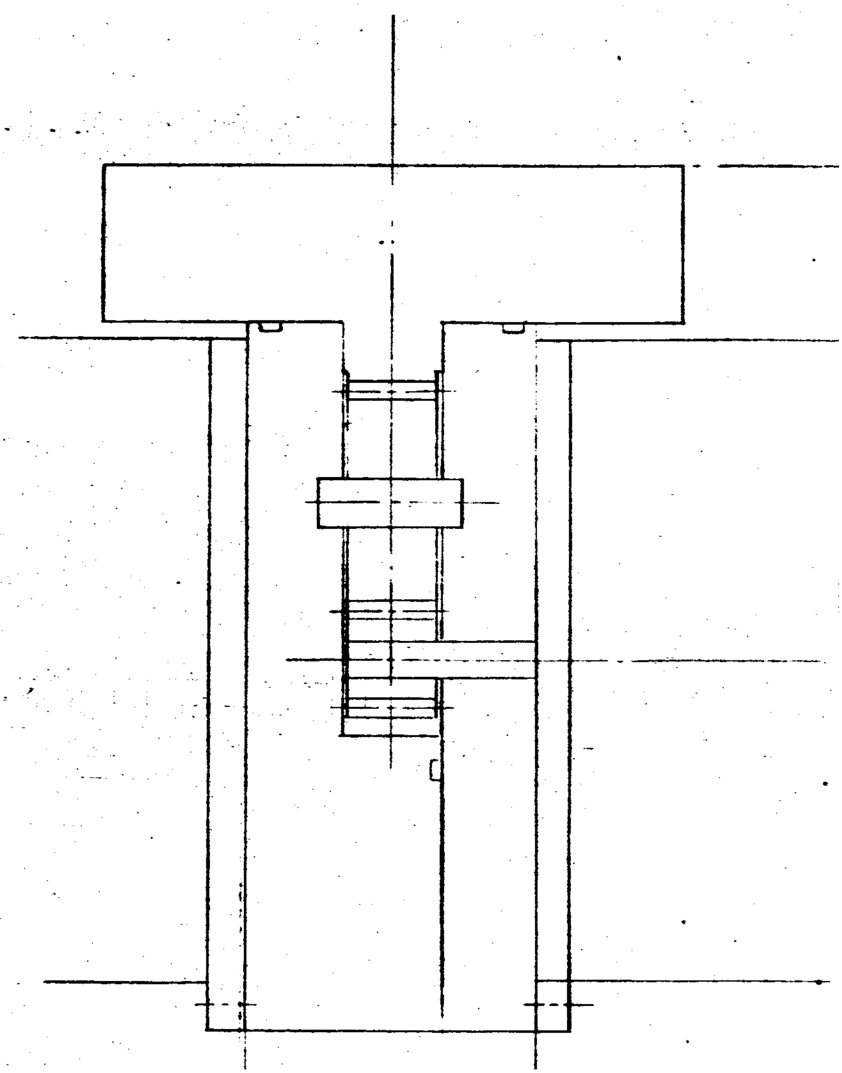
WTJ $\frac{1}{4}$ SCALE 7-1-65

B.8:11

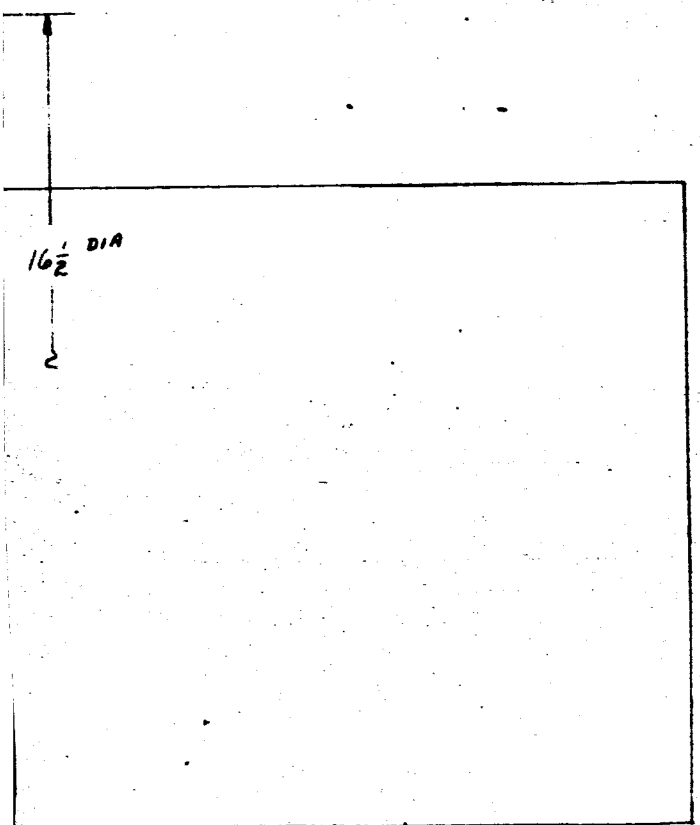
FIGURE 3

6

TOP 1

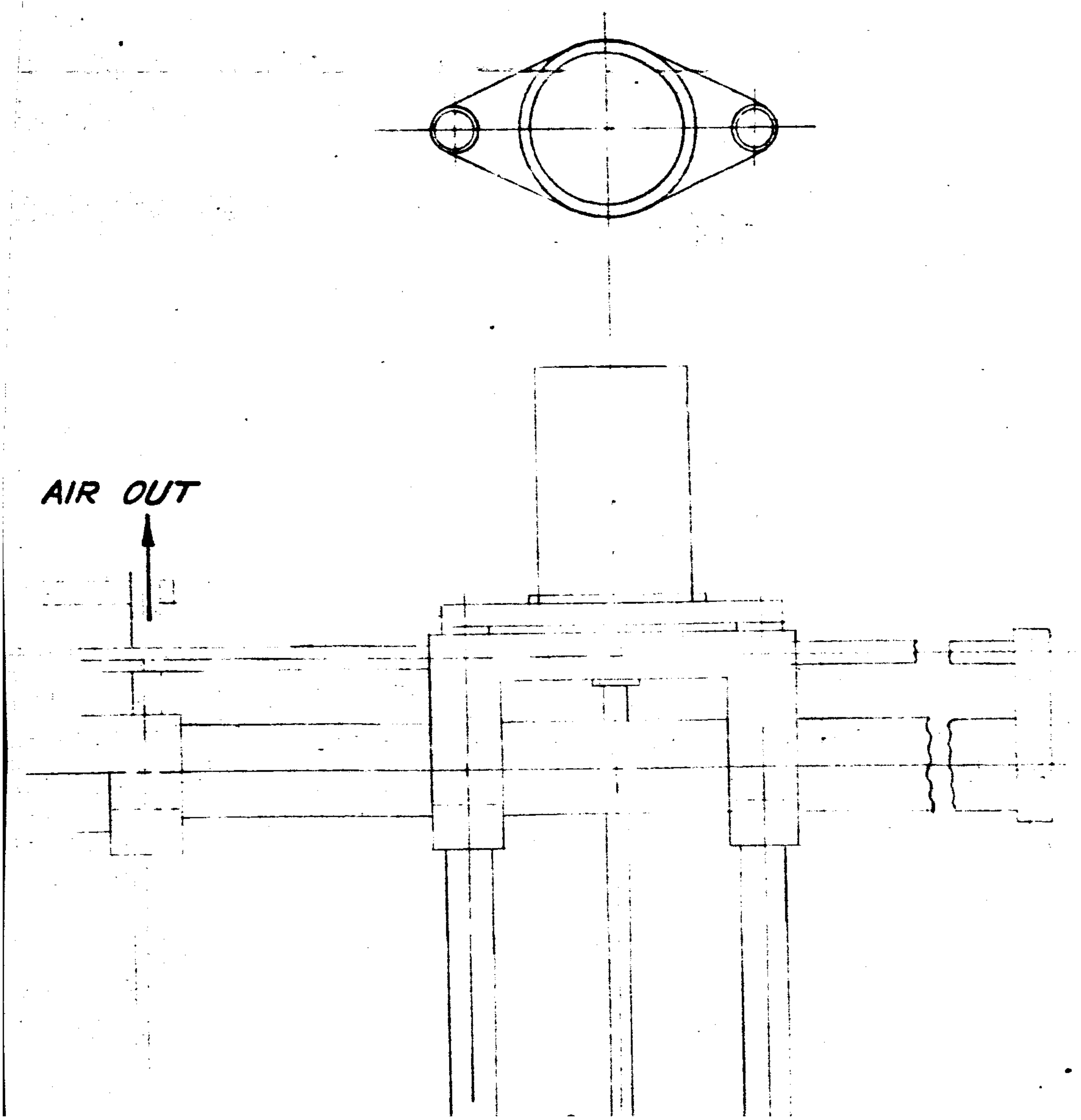


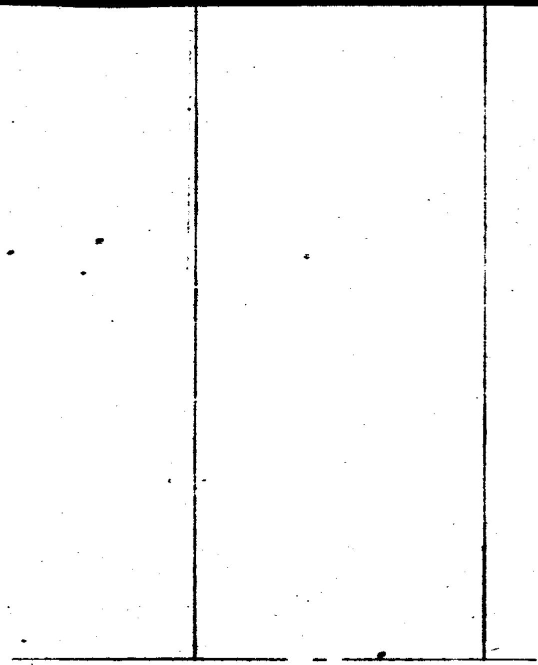
-2-



3

RE-ORDER No. 65-75-7



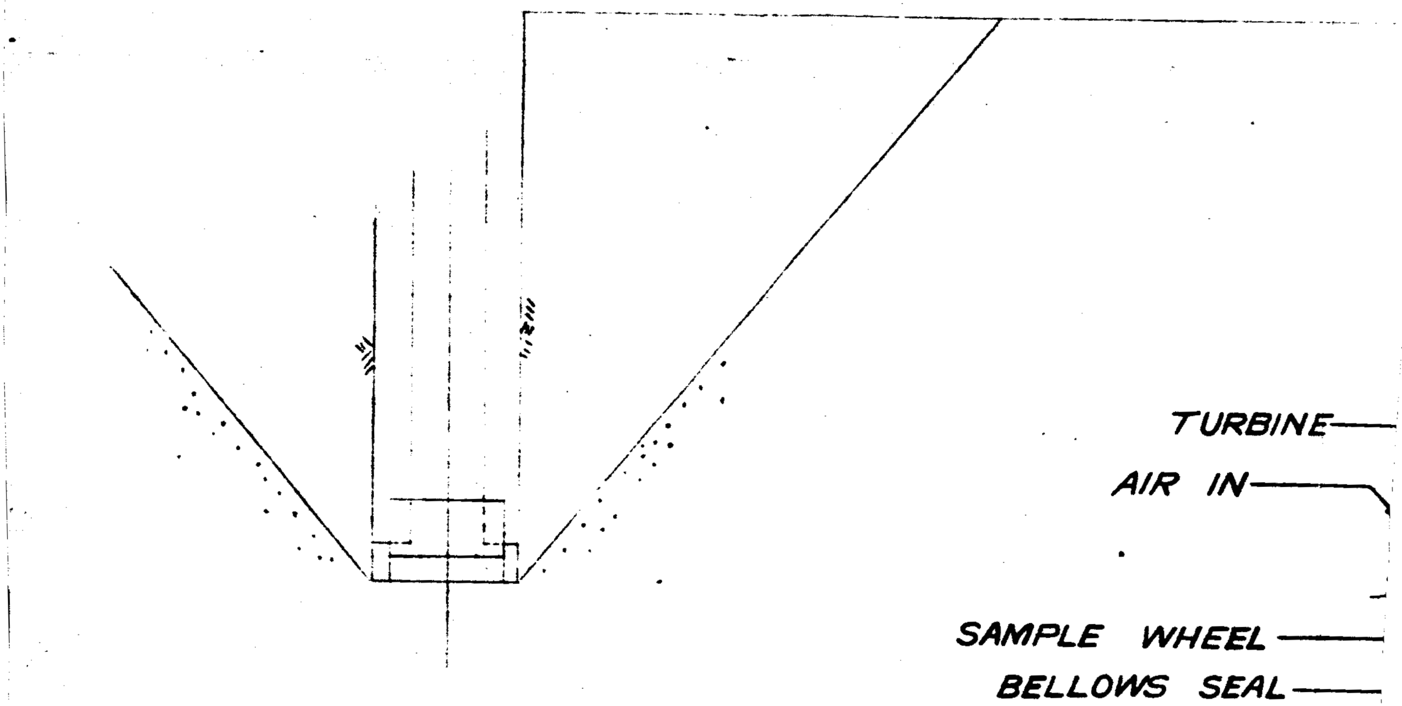


WHEEL DETAIL

FULL SCALE

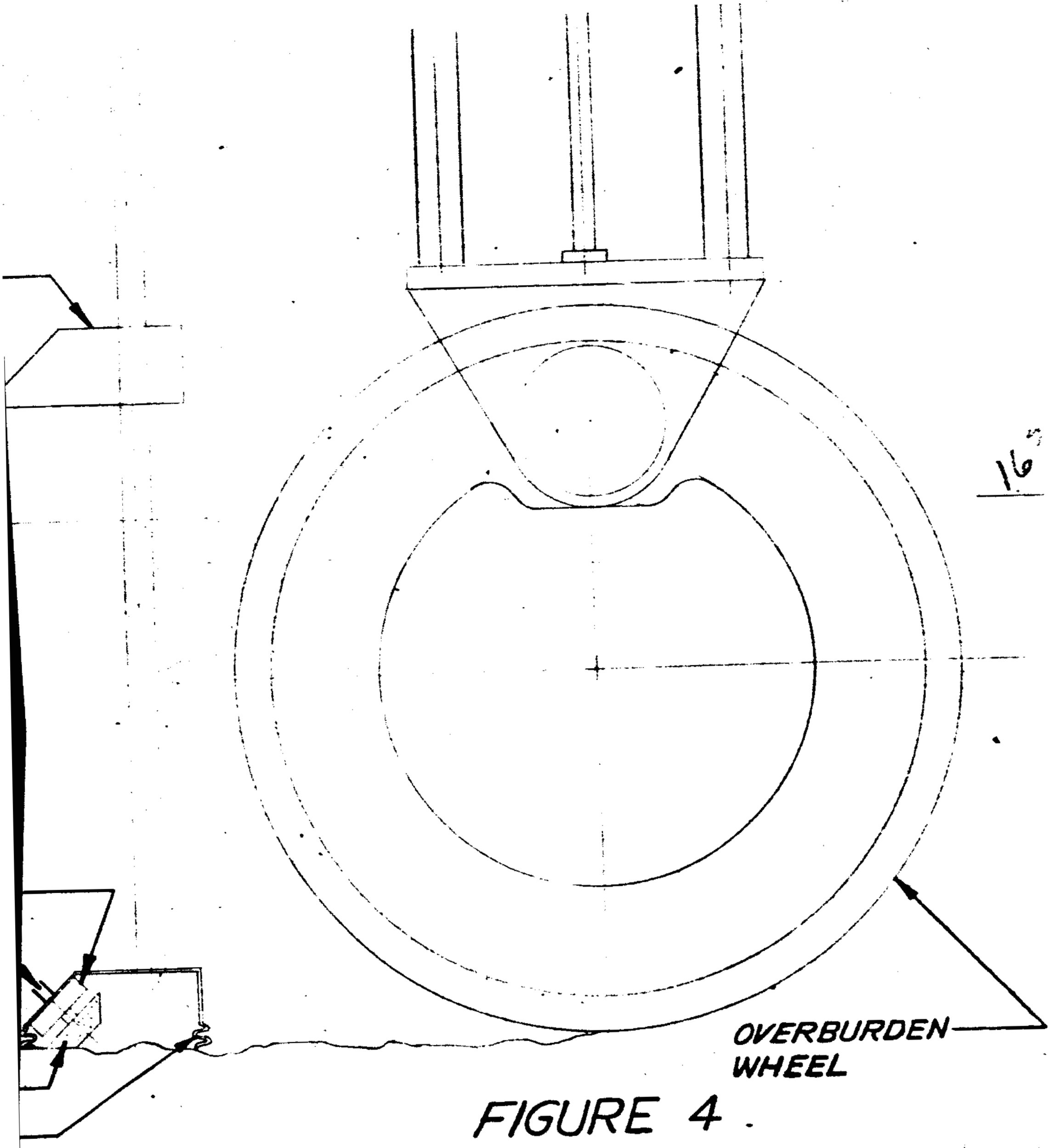
BOTTOM 4

RETRACTED POSITION



$\frac{1}{4}$ SCALE

.5



16

FIGURE 4.

45 30 003 7

W.T. JONES 7-12-65

B.8.12

6

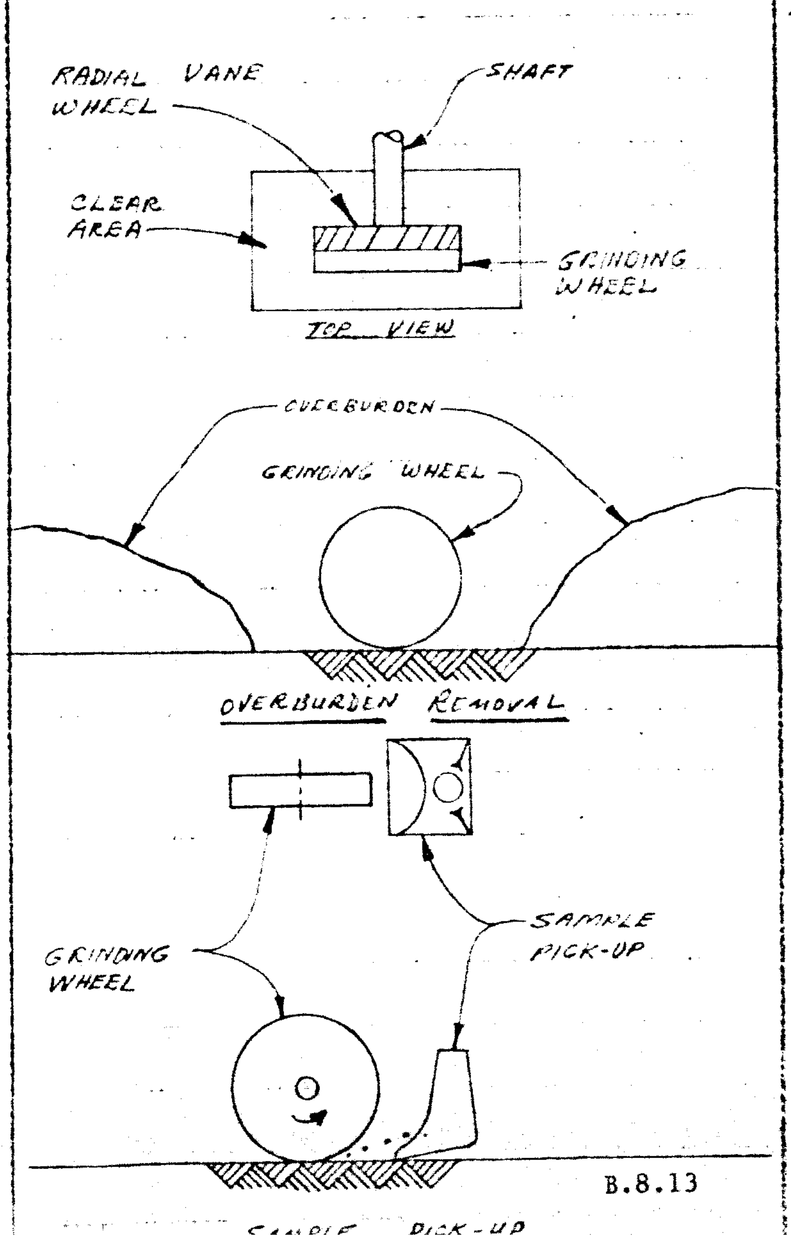
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: [illegible]

DESCRIPTION: ELECTRIC OR AIR DRIVEN GRINDING WHEEL TO SAMPLE HARDPAN, WITH RADIAL VANE WHEEL TO CLEAR AN AREA OF OVERBURDEN.

SKETCH:



ADVANTAGES: ① RADIAL VANES ACT AS PADDLES TO THROW OVERBURDEN OUT OF THE WAY, GRINDING WHEEL CUTS THRU COHESIVE OVERBURDEN AND BLAST OF AIR OUT THRU RADIAL VANES PROVIDES A ROCK SURFACE COMPLETELY FREE OF DUST IN THE AREA TO BE SAMPLED. ② RPM'S OF WHEEL CAN BE VERY HIGH, HENSE LOWERING THE POWER OF THE DRIVE MOTOR.

DISADVANTAGES: ① DESIGN PROBLEM: BEARINGS FOR HIGH SPEED ROTATION IN VACUUM. ② DESIGN PROBLEM: MECHANISM FOR COVERING A LARGE ENOUGH AREA IN WHICH TO SAMPLE THE ROCK. ③ DUST CLOUD PRESENTS PROBLEM OF VISUAL MONITORING. DUST SETTLING ON SPACE CRAFT UPSETS HEAT BALANCE.

DISPOSITION:

B.8.13

CONCEPT NO. 12

RE-ORDER No

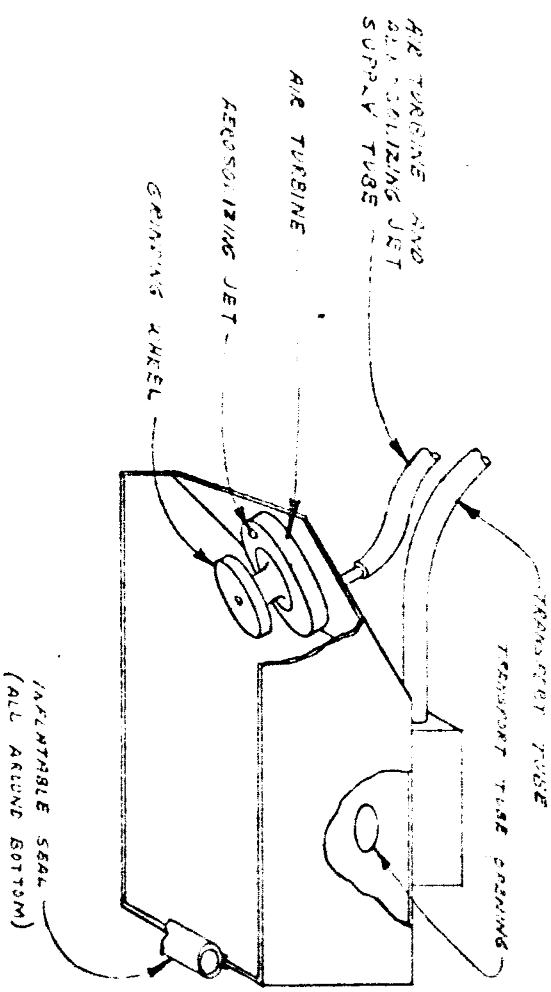
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: WTJ

DESCRIPTION: MODIFIED LITTON INDUSTRIES AEROSOLIZING UNIT AS SHOWN ON PAGE 2-36 OF THEIR REPORT ON CONTRACT JPL 950771. USE GRINDING WHEEL TO TAKE SAMPLE AFTER OVERBURDEN IS REMOVED. INFLATABLE SEAL BETWEEN BOX AND ROCK PREVENTS EXTREME GAS LOSS.

SKETCH:



ADVANTAGES: GAS TRANSPORT IN A CLOSED SYSTEM, THEREFORE MINIMUM GAS LEAKAGE.

DISADVANTAGES: SEALING TO UNEVEN ROCK.

DISPOSITION:

CONCEPT NO. 12A

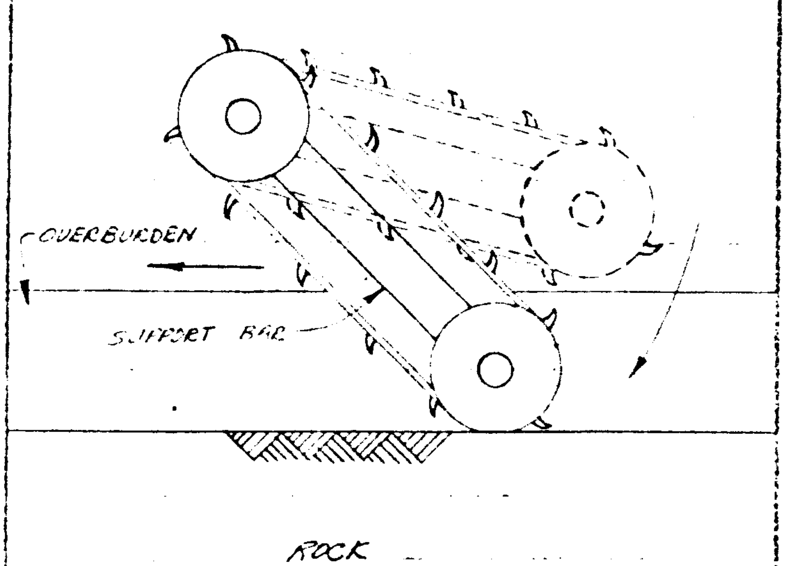
Concept Sheet

Geologic Sample Acquisition & Transport Device

Date: 4-29-85 **By:** [illegible]

Description: Chain cutter to remove overburden. Sample rock with another device mounted in support bar.

Sketch:



Advantages: Can scarf a large area easily.

Disadvantages: ① In order to remove small overburden particles on rough rock surface, it must dig into rock. ② Two types of cutters required, one for removing dust and one for cutting cohesive overburden and hard rock. ③ Dust problem - visibility and settling on spacecraft.

Disposition:

B.8.15

Concept No. 13

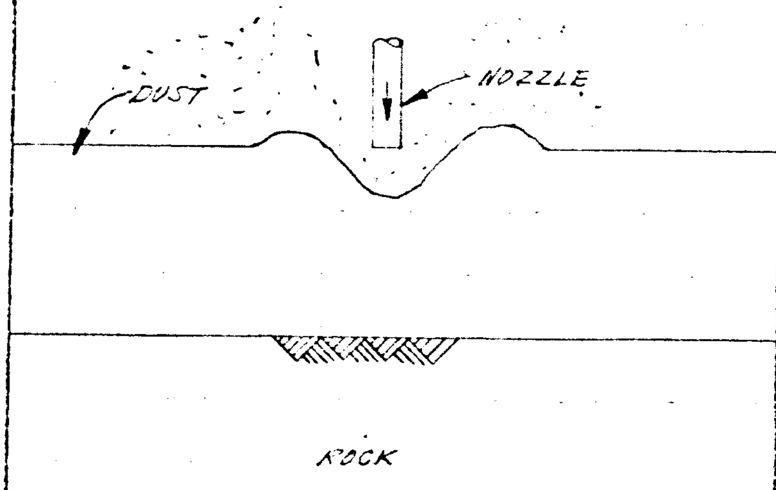
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: RCF

DESCRIPTION: BLOW OUT CRATER OF NON COHESIVE MATERIAL WITH AIR.

SKETCH:



ADVANTAGES: (1) SIMPLICITY OF SYSTEM. (2) OVERBURDEN REMOVED COMPLETELY FROM AREA OF ROCK TO BE DRILLED.

DISADVANTAGES: (1) WILL NOT PERFORM IF OVERBURDEN IS COHESIVE OR CONTAINS LARGE PIECES OF RUBBLE. (2) WEIGHT OF GAS AND CONTAINER. (3) VISIBILITY OBSCURED; SETTLING ON SPACECRAFT; SETTLING TIME

DISPOSITION:

CONCEPT NO. 14

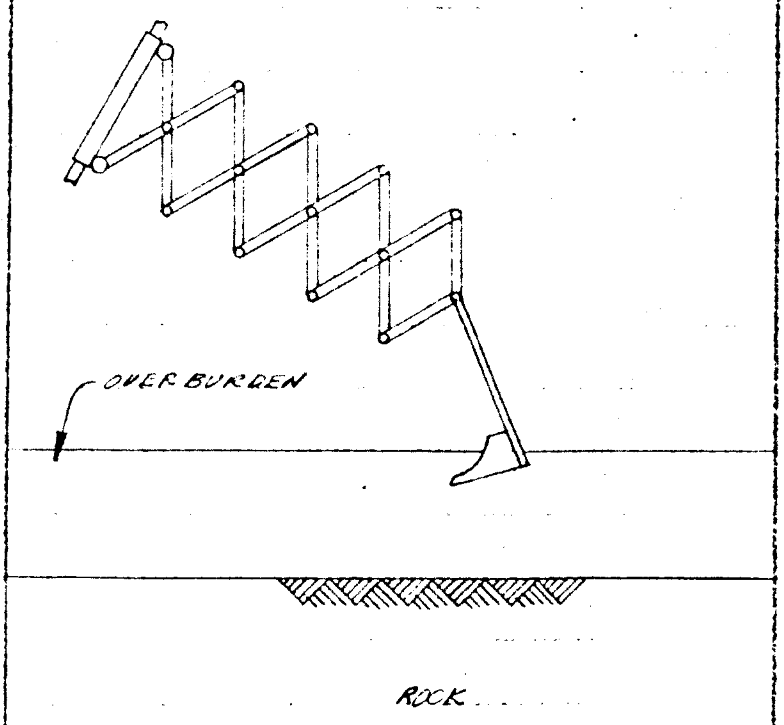
Concept Sheet

Geologic Sample Acquisition & Transport Device

Date: 4-27-65 **By:** WTJ

Description: Surveyor sampling system. Extendible bucket working in cohesive and non-cohesive formation.

Sketch:



Advantages: ① Simplicity ② Can be used to clear overburden away as well as sample overburden.

Disadvantages: ① Numerous pin joints - lubrication in vacuum. ② Clearing a specified area to one foot depth would be very slow.

Disposition:

Concept No. 15

An idea using the basic principles of concept 19 is shown by Figure 1. This concept would consist of a 4 station indexing mechanism. At the first station the casing and the removable bit are drilled into the formation. The casing would be sealed at this point in the operation with the grouting material. The casing and bit would be rotated with a mechanism which could be disconnected from the casing and withdrawn from the work area. This mechanism could be patterned after a power swivel. The material displaced by the bit and the casing could be removed by the use of auger flights on the outside of the casing or by gas pressure blowing it aside.

After the bit and casing rotating device is moved out of position, the explosion bolts are fired or the catch mechanism is released. This action frees the removable bit. At station two a probe is lowered into the casing and secures the bit and is retracted out of the casing and out of the work area. While the indexing operation occurs, station three, the drilling and sampling device, is moved into position over the casing. The drill is lowered into the casing to the formation and takes the desired sample. The fourth station would be, in the case of the storage bit as used here, to retract the drill and drop the material into the sample container.

This concept offers only the advantage of the elimination of the large cone shaped casing as proposed in concept 19. A disadvantage is the requirement of a mechanism to rotate the casing and bit, to release itself from the casing and then be retracted from the work area.

The drilling and sampling device as shown by Figure 2 is an attempt to eliminate the indexing operations that are required for Figure 1 and concept 19. The operation and main features are outlined below.

The main structural tube, the drill motor and percussor device, the feed screw arrangement and guides are similar to the ones proposed for the vibrating screw conveyor. The drilling tool is a percussor type. The drill stem, the casing and the bit all rotate as a single unit. The rotation and impact blows are transmitted to the casing and bit through the drill stem and adapter which connects the drill stem to the casing. After drilling through the overburden and into the rock formation to seat itself, the drilling operation is stopped and the grouting operation is started. The cuttings produced have been removed by the gas transport system as shown by Figure 2. After the grouting operation is completed and the formation stabilized, the pyrotechnic device is fired and the adapter is sheared into two pieces. After the adapter has been sheared the drilling operation is started again and the desired sample can be obtained from the formation. The casing will remain stationary and held in the vertical position by the casing supports while the drill and drill stem advance into the formation to secure the desired sample.

Figure 3 shows the same basic drilling and sampling device as shown by Figure 2 except for the method of sealing the overburden. The sealing device consists of an inflatable bag protected from damage by a thin slotted ring which is attached to the casing. See Figure 3 for the details.

CONCLUSIONS:

1. The concepts as shown by Figures 1, 2 and 3 and concept number 19 would all probably be able to drill and acquire the desired sample.

2. Concepts as shown by Figures 2 and 3 are simpler in design.

3. The concept as shown by Figure 3 has the most promise.

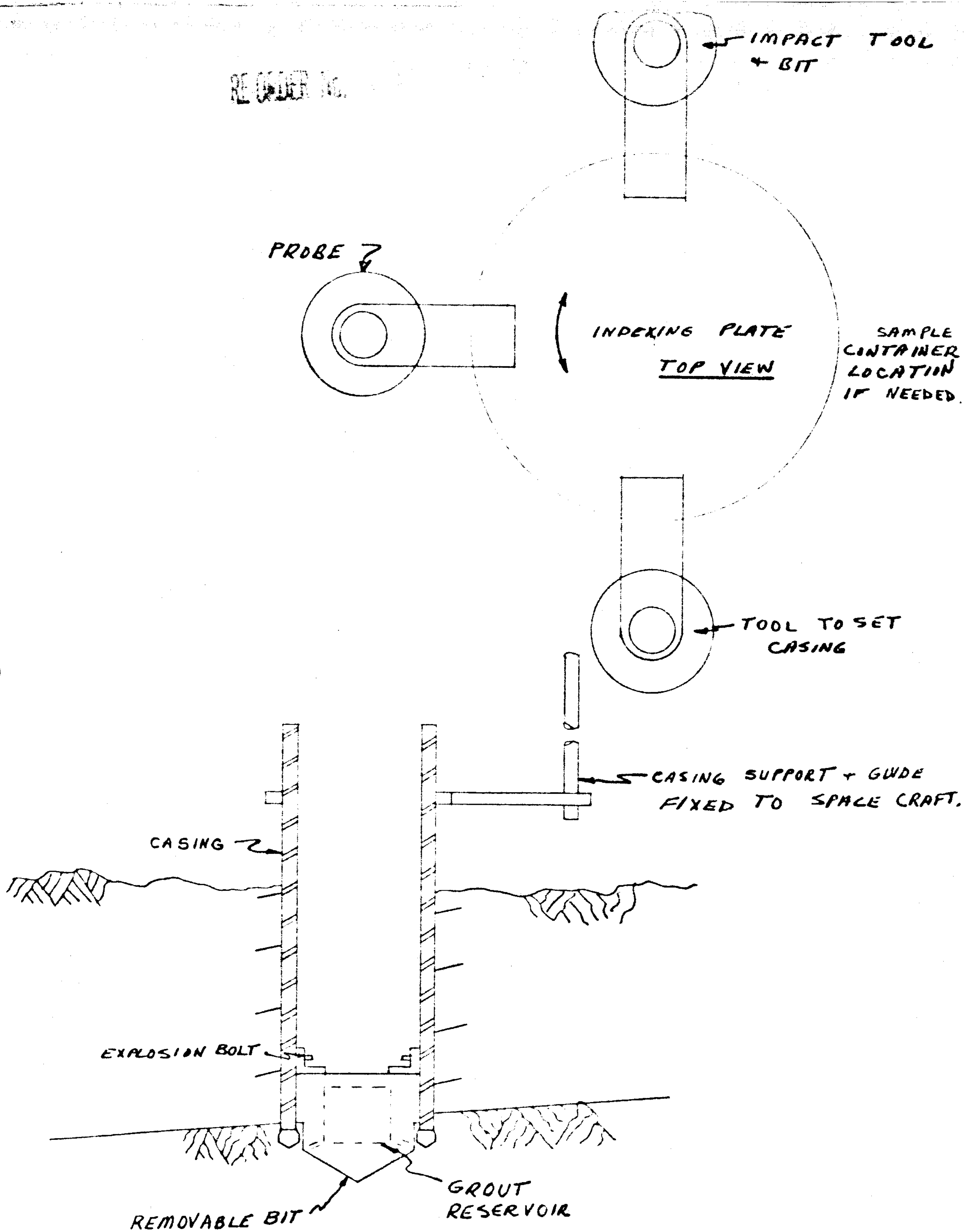


FIG 1

DLI 6-24-65

45 30 003 7

APPENDIX B.9

REPORT OF INVESTIGATION

DOUBLE WALL TUBE TO SEAL OVERBURDEN FROM SAMPLE

INTRODUCTION:

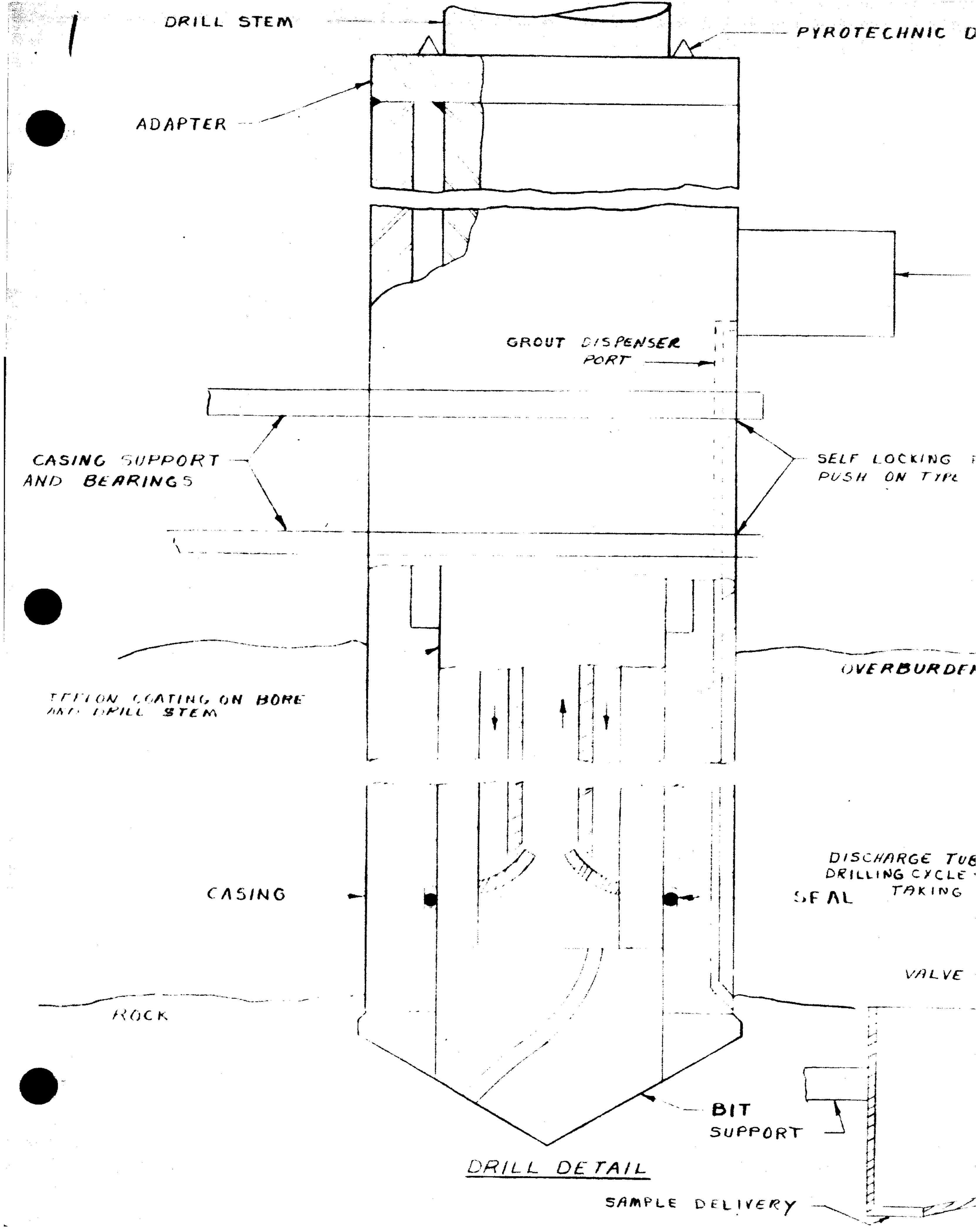
This investigation covers concepts 16 and 19, a method of sealing out the overburden and using the casing as a means to get to and secure the desired sample. The concept of the use of a double wall tube and gas transport is covered in a separate Report of Investigation.

INVESTIGATION:

Concept number 16 is not feasible. The disadvantages as outlined on the concept sheet point out the salient features that make this device undesirable. No additional time will be spent studying this concept.

Concept number 19 appears to be a workable system. I will not delve into the advantages of this system in this I.O.C. as they are already outlined on the concept sheet. Some problem areas that come to mind are: (1) Power requirements to turn the cone and bit plug (greater or less than impact tool requirements?); (2) Is a seal or grouting material necessary if the cone is isolated from impact tool operation?; (3) Plug release mechanism; (4) Weight of total system may make it undesirable; (5) Can we get a seal or grout material that would meet or work in the lunar environment? Some of these questions can be answered through the studies made of the other concepts. I do not believe that any of these areas will be an insurmountable design problem.

The concepts as proposed for the screw conveyor and gas transport may not work at all if a problem develops because of leaking material down the annular area adjacent to the drill stem due to the vibrating motion of the drill stem. Concept 19 appears to have this problem area solved if we can get an effective grouting material. This one advantage makes concept 19 superior to the others that I have studied. However, we still have the problem of transporting the sample to the surface. This problem probably can be solved by the gas transport system or other mechanical devices such as the calyx basket or a bit storage container combination such as the Hughes Aircraft bit.



DRILL DETAIL

EVICE 2

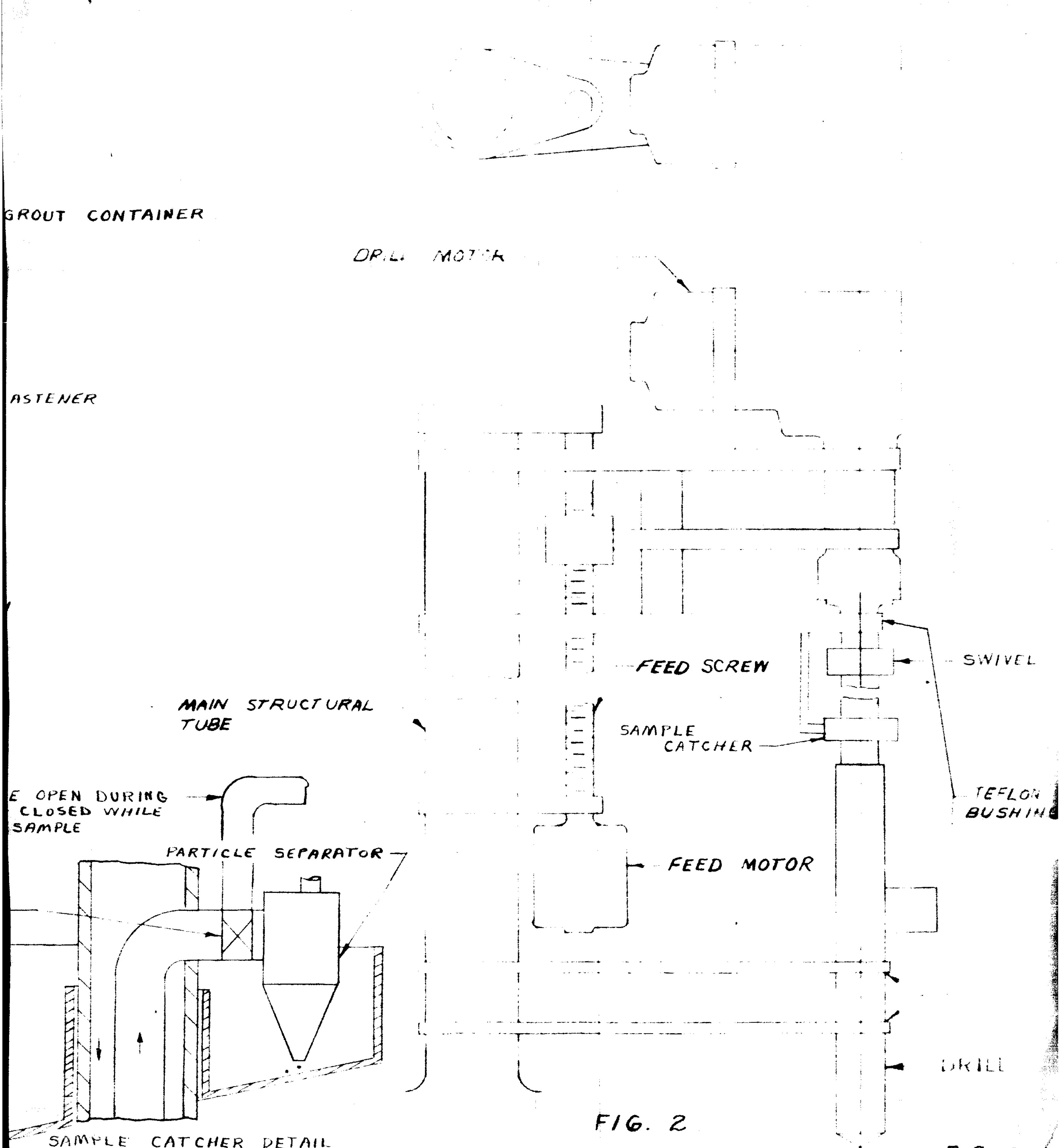
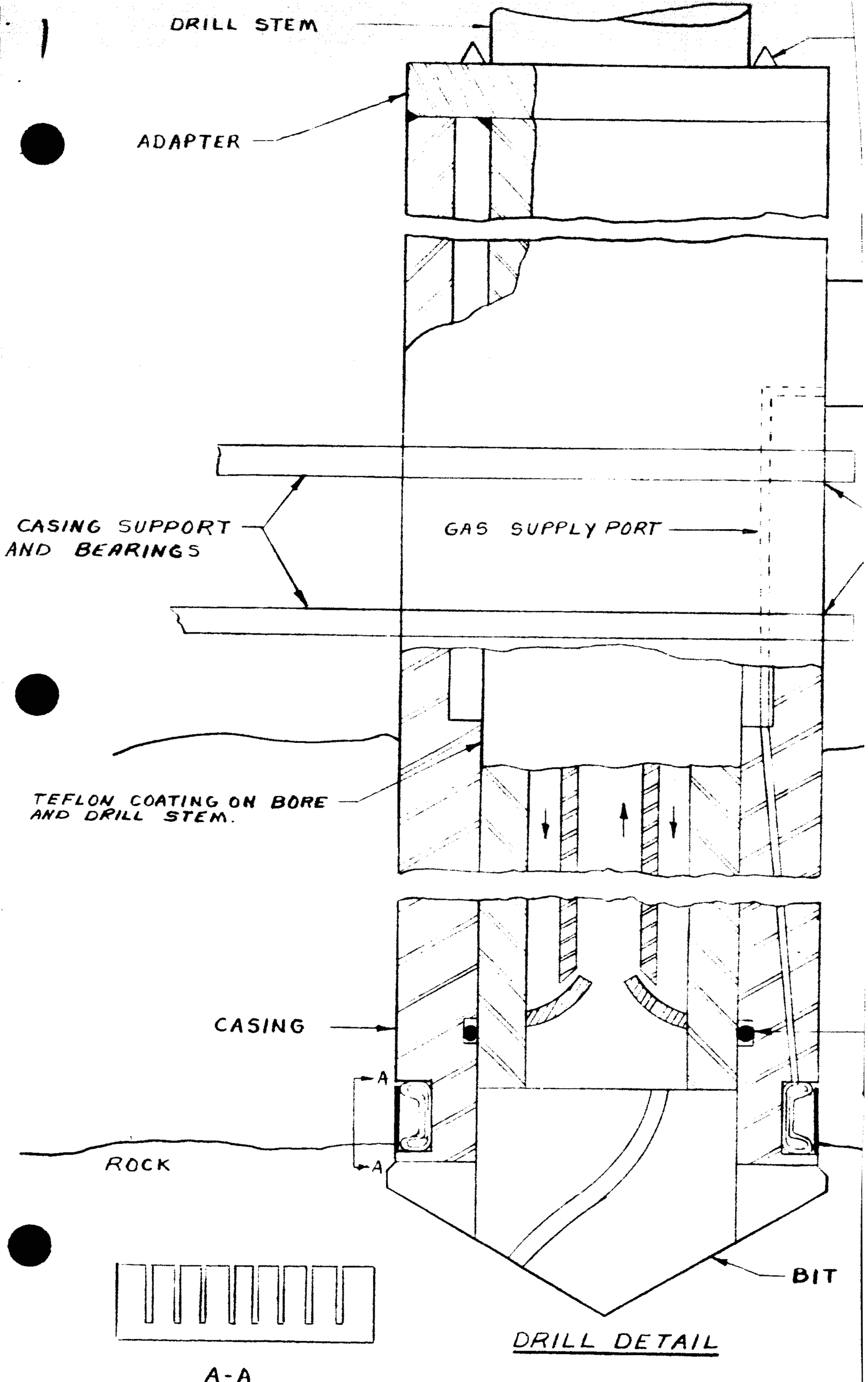


FIG. 2

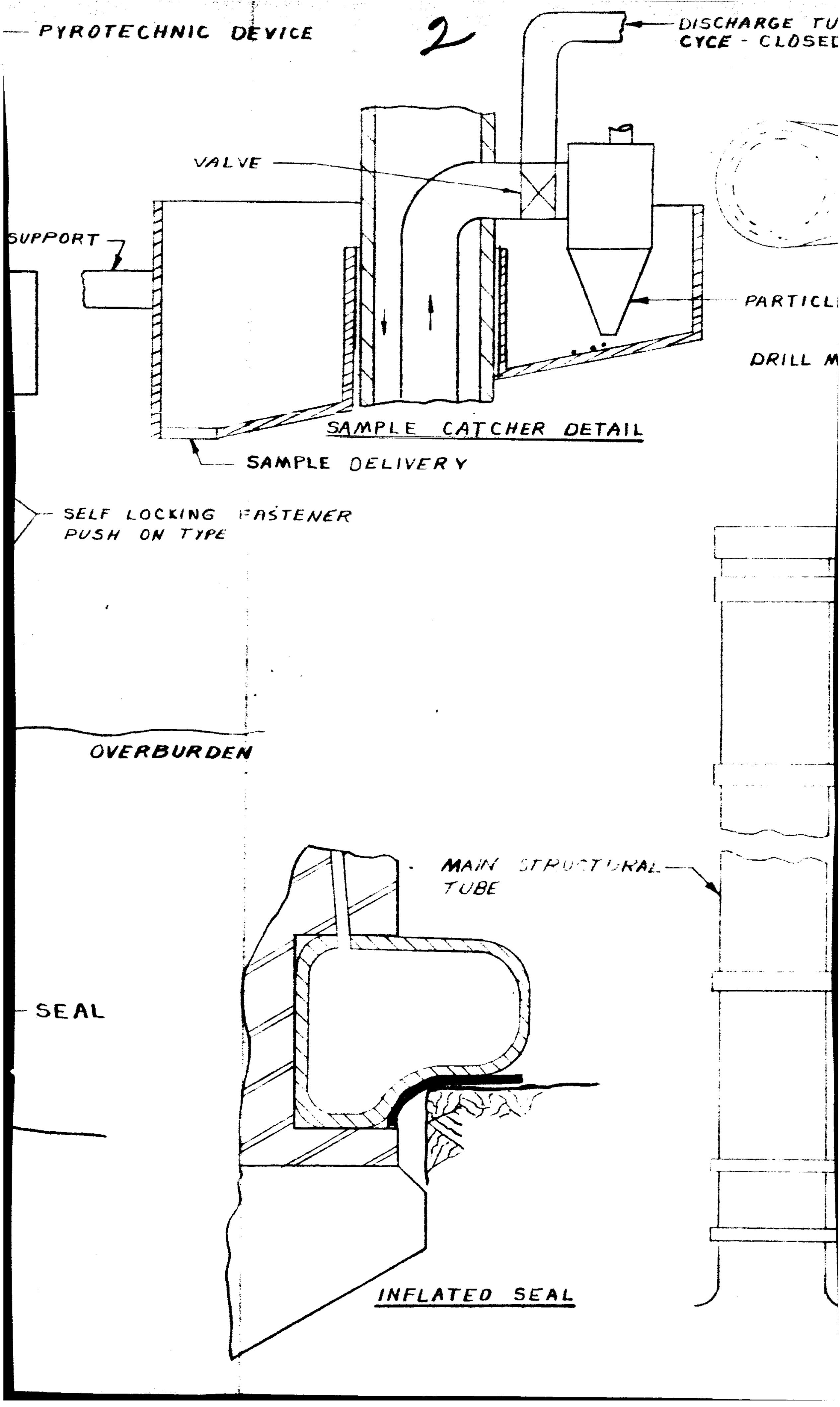
45 30 003 7

B.9.5

1



DRILL DETAIL


PYROTECHNIC DEVICE
2
DISCHARGE TU
CYCE - CLOSED
VALVE
SUPPORT
PARTICL
DRILL M
SAMPLE CATCHER DETAIL
SAMPLE DELIVERY
SELF LOCKING FASTENER
PUSH ON TYPE
OVERBURDEN
MAIN STRUCTURAL
TUBE
SEAL
INFLATED SEAL

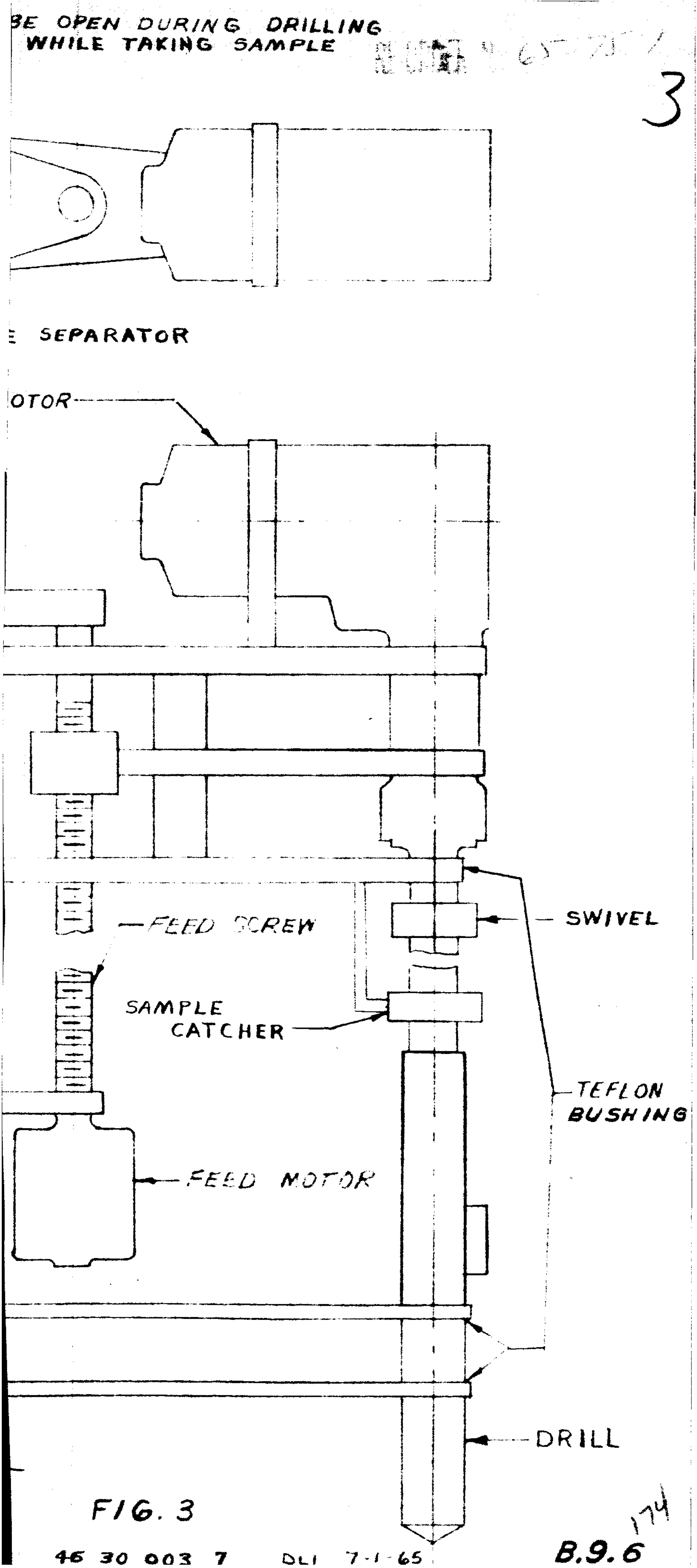


FIG. 3

46 30 003 7 DLI 7-1-65

B.9.6

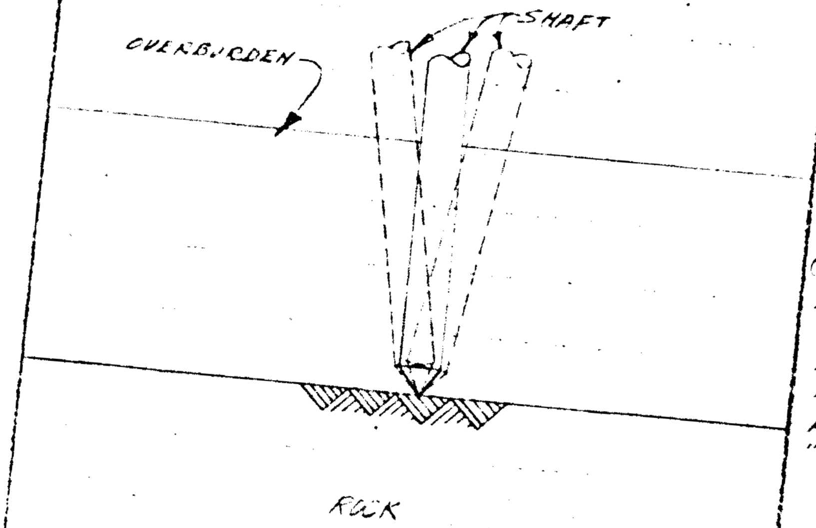
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: RJF

DESCRIPTION: POINTED HOLLOW SHAFT WIGGLED THRU OVERBURDEN. DISCARD POINT BY BLOWING OFF. SEAL CASING TO HARDPAN. SAMPLE OVERBURDEN AT TOP OR BOTTOM.

SKETCH:



ADVANTAGES: SIMPLE PRINCIPLE.

DISADVANTAGES: ① DESIGN PROBLEM: MECHANISM TO PROVIDE WIGGLE AND THRUST AT THE SAME TIME? ② DESIGN PROBLEM: HOW TO GET POINTED CAP OUT OF WAY FOR DRILLING IN ROCK. ③ THRUST REQUIRED FOR THIS WOULD BE HIGHER THAN THAT REQUIRED FOR ANY TYPE OF CUTTING ACTION. ④ PROBABLY WOULD HAVE TO DEVELOP AN ADJUSTABLE MAGNITUDE "WIGGLE" AS PENETRATION INCREASED, SO THAT "WIGGLE" AT TOP WOULD BE DECREASED.

DISPOSITION:

CONCEPT NO. 16

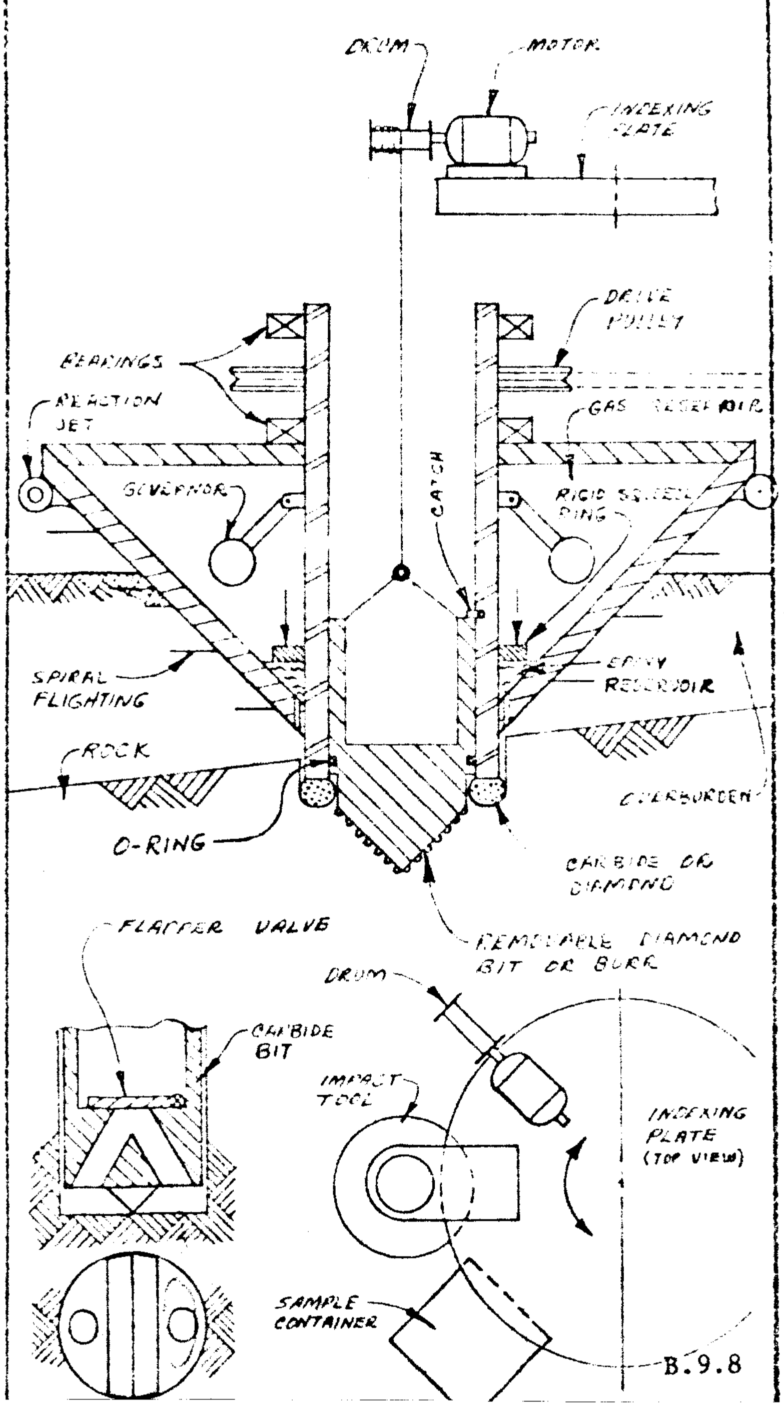
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 5-6-65 BY: ROB

DESCRIPTION: CONE WITH EXTERNAL SPIRAL FLIGHTS TO CENTRIFUGALLY EXPELL OVERBURDEN MATERIAL. HOLLOW CENTER HAS A BIT AS PLUG, WHICH CAN BE REMOVED UPON SEATING IN HARDPAN TO PROVIDE ACCESS FOR DRILLING TOOL. CONE POSSIBLY DRIVEN WITH JETS OR MECHANICALLY. FLAPPER VALVE ASSEMBLY SHOWN WITH DRILL STEM FOR CUTTINGS RETRIEVAL.

SKETCH:



ADVANTAGES: ① REQUIRES LITTLE POWER, UTILIZING MOMENTUM IN CONE TO NEGOTIATE OVERBURDEN. FED VERY SLOWLY INTO OVERBURDEN. ② PROVIDES STABILIZED BASE FOR SUBSEQUENT DRILLING OPERATIONS INVOLVING PERCUSSION ACTION. ③ PROVIDES A SEALING MEANS. ④ EXCLUDES CONTAMINANT. ⑤ RECOVERS SAMPLE WITHOUT GAS SYSTEM. ⑥ WILL SEAT ON UNEVEN HARDPAN. ⑦ PROVIDES STARTING HOLE FOR SAMPLE DRILLING.

DISADVANTAGES: ① SEQUENCED OPERATIONS, REQUIRING A NUMBER OF CONTROLS AND FEEDBACK. ② SEALING, OR GROUTING MATERIAL WOULD HAVE TO BE DEVELOPED TO WORK IN LUNAR ATMOSPHERE.

DISPOSITION:

CONCEPT NO. 19

APPENDIX B.10

REPORT OF INVESTIGATION

SAMPLING BY USE OF EXPLOSIVES

INTRODUCTION:

This investigation relates to the use of explosives and/or explosively actuated devices for the purpose of lunar sampling. In particular, Concepts 17, 18, and 18A are to be evaluated. A brief description of each follows:

Concept 17 - Use dynamite to remove overburden.

Concept 18 - A pattern of explosive driven penetrators, operating inside a casing, producing rubble and utilizing the confined products of the explosives to lift the rubble.

Concept 18A- Explosive type coring device with tethered bullet. Concept similar to M. M. Kinley patent 3,172,486 dated 3-9-65.

INVESTIGATION:

Concept 17

This idea is not restricted to use of dynamite exclusively, but encompasses any explosive-type system, whether it be chemical or mechanical.

In evaluating this concept, the approach shall first be taken that an explosive device is available or can be developed such that its strength, handling characteristics, safety, and other operational requirements under the severe lunar environmental conditions can all be met. Given such a device, is it then desirable to use it to remove overburden?

Considerable work has been done in establishing a basis for predicting explosive crater geometry, based on both small and large scale tests, in References 17 and 18. Curves have been developed for air bursts, detonations air-medium interface, and buried detonations. In order to get a "feel" of the capability of explosives to develop craters with depths of one foot, the following tabulation was developed:

Material	Crater Depth, Ft.	Required Charge, Lb.	Burial Depth, Ft.	Crater Dia., Ft.
Plaster of Paris	1.00	1000	0	12.0
	1.05	343	3.5	14.0
	1.00	64	4.0	12.0
	1.00	16.6	3.75	11.0
Concrete Mortar	1.00	8	0	4.4
	1.00	1	.5	2.8
	1.20	1	1.0	3.6
	1.00	1	1.5	4.6
Rockville Granite	1.00	64	0	8.0
	.96	27	1.5	9.0
	1.00	16.6	2.5	11.0
	1.00	11	3.33	10.7
Desert Alluvium NTS	1.00	6	0	5.64
	1.00	1.81	.49	4.64

The burial depths above are based on the location of the center of the explosive mass. The tabulation shows that the material most probably weakest in tension, desert alluvium, requires the smallest charge, 6 lab., to produce a one ft. deep crater, at zero burial depth. Note however, that the predicted crater diameter is over 5-1/2 ft.

In the application of explosives to remove overburden, a number of objectionable points seem rather obvious, at this stage:

1. While lesser charge weights would be required to achieve a one foot deep crater, the mechanical complications of "burying" charges below the lunar surface would make this technique undesirable.

2. Use of explosives situated at the lunar surface results in higher charge weights and larger crater diameters. The size of the resulting crater would require remote blasting, at least to the extent of not disturbing the material upon which the spacecraft rests.

3. Even more remote positioning of the surface detonation would be required to protect the spacecraft and other equipment from high velocity ejecta and air blast effects, propagated in a near-horizontal direction.

While none of the foregoing data predicts results of an explosive event in lunar dust, or rubble, under hard vacuum conditions, it would appear that the case of NTS desert alluvium would be the nearest comparison. It would also appear that Items 2 and 3 above would be sufficient cause to reject the idea of use of explosives to remove overburden, based upon strictly application considerations, without any thought having been given to problems connected with development of explosives compatible with the extreme environmental temperature variations.

Concept 18

Reference 16 cites a great deal of data related to dynamic rock penetration tests with explosively driven projectiles. Penetration and crater volumes for variously shaped projectiles in various materials can be related to consumed energy, based on atmospheric tests. The writer feels that Concept 18 can be evaluated on a much more macroscopic basis, however. The required sample volume, 3 cc., is of such small magnitude as to reject the idea of a multi-penetrator setup for a single-shot application, due to complexity alone. The idea of a short burst of explosive product gases being used to transport the resulting rubble also appears to be incompatible with simplicity of design, inasmuch as venting of the gases from the individual combustion chambers to the vicinity of the rubble, or below, would be a necessary criteria for lifting. Otherwise, an adverse effect, that of holding down the rubble, would result as the gas expands and vents into a sample collector.

A more desirable approch would appear to be in the direction of a single penetrator, driven so that it impacts repeatedly, with a controlled gas transport system. If indeed, gas transport is desirable at all, the ability to control pressures and flow rates, as well as the ability to seal casing against formation, is necessary, but would be of infinitely greater difficulty to achieve in the explosive penetrator situation than in the case where gas flow is directed from a pressure vessel or gas generator.

Concept 18A

The patent by M. M. Kinley appears to be a reasonable structural representation of the basic ideas forwarded in Concept 18A. The evaluation of this concept is based largely on comments from the Welex Corporation. A leading firm dealing in oilfield wire line services including perforating and explosive sidewall coring (Reference 19). To quote Ref. 19, "Current art as practiced in coring of wells does not have the capability of obtaining and retrieving a three (3) cubic centimeter sample (of basalt or granite). Several conditions exist that prevent recovery of cores in formations of basalt or granite, among them being; (a) Brittle fracture of the rock occurs under the high loading rates imposed by explosive devices. (b) The sample dislodged from the rock is so fragmented that retention in the conventional core barrel is most unlikely, particularly when consideration is given to the different forces which act upon any retained sample, as the core barrel is returned to the surface from coring depth".

"It might be possible to fragment basalt or granite to produce the required sample with a modification of currently used designs. However, retrieving a sample in a barrel would be most unlikely and design limitations created by vessel dimensions and the necessary limited weight of the coring device would open this avenue to question. The basis for this reply lies in experimental work conducted by Welex".

"Current art in regard to the use of explosive devices within the proposed environment leaves several questions yet to be answered. Most information on explosives and metals used to construct explosive devices covers the range from approx. -100°F to -240°F. Development work should cover this area".

"One predictable result of the lower temperature on explosives would be the reduction in generated force since a portion of the released chemical energy would be dissipated in raising the temperature of the explosive to the threshold value for deflagration or detonation as the case may be. Also, with a hard vacuum, it might be well to consider an explosive which contains a positive oxygen balance in the explosive products as fired in an earth atmosphere".

"Low temperature studies of metals has indicated that selection of the proper material for explosive devices would be most critical. Low temperature drastically decreases the impact resistant properties of some metals while other materials are not so effected".

Even if the foregoing commentary were in a more positive tone, additional problems are foreseen in application of this concept. Retention of dust or rubble in the core barrel would not be possible. In harder formations, if we indeed were fortunate enough to be able to design a core barrel such that a sample could be compacted (though fractured) into it, the problem of punching it out into the sample collector, and subsequent sizing for analysis would remain.

CONCLUSIONS:

1. Concept 17 is rejected as being too hazardous to the spacecraft and other equipment, from the standpoint of high-velocity ejecta and also of jeopardizing spacecraft support surfaces.

2. Concept 18 is rejected as being too complex, and as offering an inadequate solution for sample transport.

3. Concept 18A is rejected on the basis that explosive coring devices cannot produce and/or recover samples from rock as hard as basalt or granite.

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Sampling by Use of Explosives

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CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: JMM

DESCRIPTION: USE DYNAMITE TO REMOVE OVERBURDEN

SKETCH: NONE

ADVANTAGES: LARGE AREA OF OVERBURDEN MATERIAL REMOVED SIMPLY.

DISADVANTAGES: ① DUST PROBLEM - VISIBILITY AND SETTLING ON SPACECRAFT. ② PROBABLY HAVE TO BE COMBINED WITH ANOTHER METHOD SUCH AS CONCEPT 14 TO ENSURE 100% REMOVAL OF DUST.

DISPOSITION:

CONCEPT NO. 17

CONCEPT SHEET

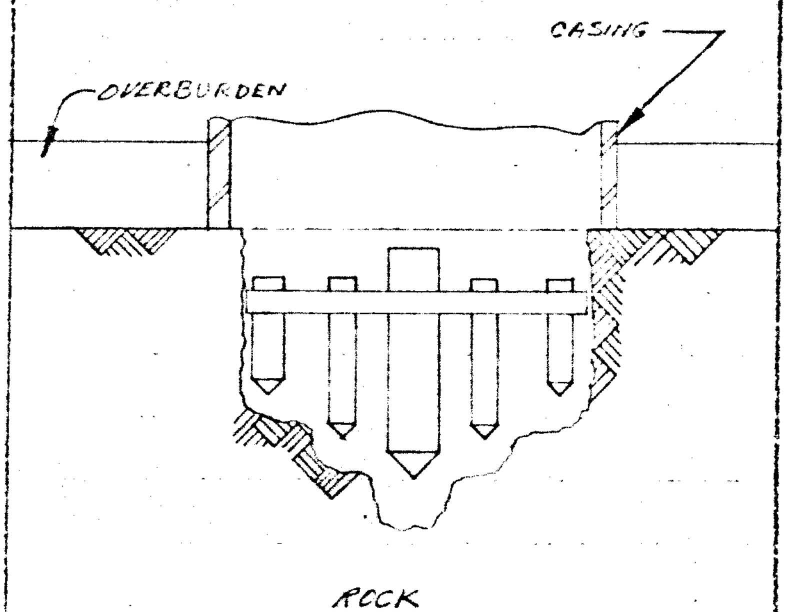
RE ORDER No.

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: JMM

DESCRIPTION: A PATTERN OF EXPLOSIVE DRIVEN PENETRATORS, OPERATING INSIDE A CASING, PRODUCING RUBBLE AND UTILIZING THE CONFINED PRODUCTS OF THE EXPLOSIVES TO LIFT THE RUBBLE.

SKETCH:



ADVANTAGES:

DISADVANTAGES:

DISPOSITION:

B.10.9

CONCEPT No. 18

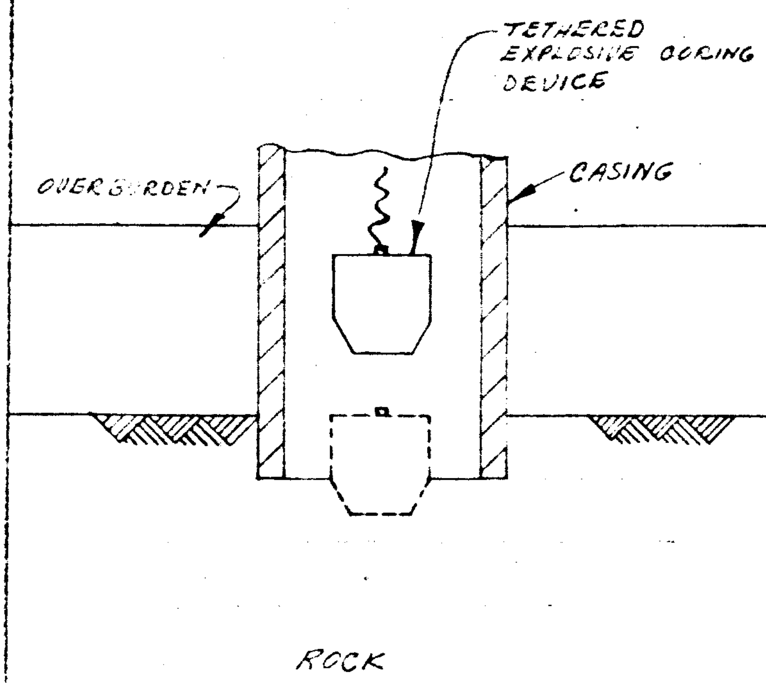
CONCEPT SHEET

GEOLOGIC SAMPLE ACQUISITION & TRANSPORT DEVICE

DATE: 4-27-65 BY: RDB

DESCRIPTION: SCHLUMBERGER TYPE EXPLOSIVE CORING DEVICE WITH TETHERED BULLET.

SKETCH:



ADVANTAGES: ① CORING METHOD WITHIN STATE OF ART. ② SLIGHTLY DECREASED VACUUM AS A RESULT OF THE EXPLOSIVE CHARGE WOULD ASSIST IN EXCLUDING OVERBURDEN CONTAMINANT. ③ EXPLOSIVE CORING IDEA CAN BE USED WITH OTHER MECHANICAL TECHNIQUES OF EXCLUDING OVERBURDEN.

DISADVANTAGES: ① FORCIBLY EXTRACTING SAMPLE FROM BULLET. MAYBE SECONDARY CHARGE FOR EXTRACTION COULD BE USED.

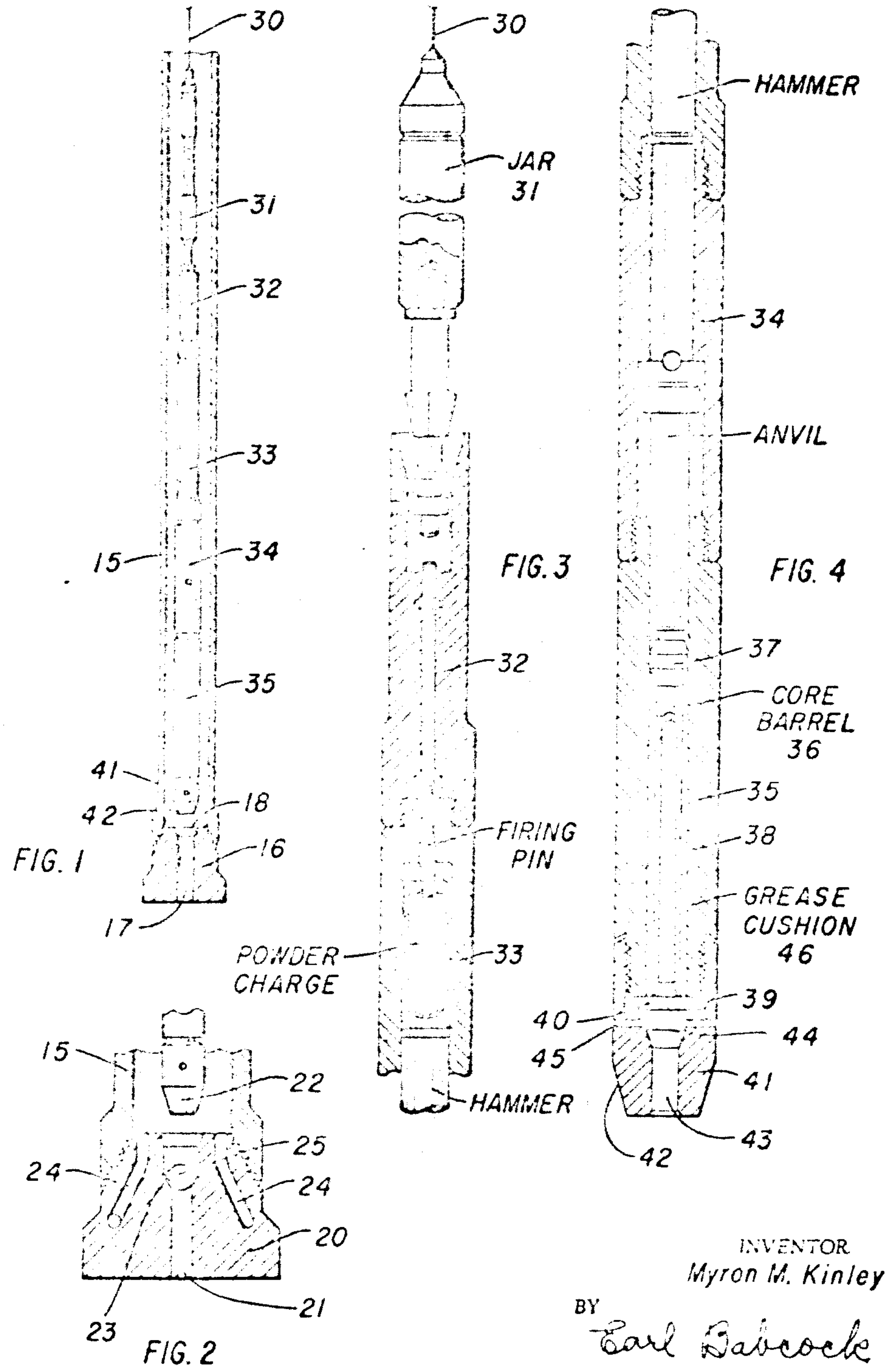
DISPOSITION:

CONCEPT NO. 18A

March 9, 1965 M. M. KINLEY 3,172,486

EXPLOSIVE-ACTUATED APPARATUS FOR TAKING CORES

Filed July 11, 1963



INVENTOR
Myron M. Kinley

BY

Earl Babcock

United States Patent Office

3,172,486

Patented Mar. 9, 1965

3,172,486

EXPLOSIVE-ACTUATED APPARATUS FOR TAKING CORES

Myron M. Kinley, 103 Maple Lane, Chickasha, Okla.

Filed July 11, 1963, Ser. No. 294,339
2 Claims. (Cl. 175—4)

This invention relates to apparatus for taking cores or samples of rock from the bottom of oil wells or the like while the wells are being drilled or reworked or reconditioned.

In the drilling of wells, it is sometimes important to know the nature of the rock or soil through which the drill bit is passing. It is well known in the art to provide a core bit for this purpose, and, in general, core bits are used when exact knowledge of the formation being drilled is desired. Some of such bits are provided with retrievable core barrels, so that a sample of the rock can be obtained by fishing the barrel out of the well without removing the drill string and bit from the well. It is also well known to take samples of the rock in wells from the side of the bore hole, such devices being generally known as side wall samplers. Side wall samplers are usually operated by explosives.

In the U.S. patent to Bannister, No. 1,955,166 granted April 17, 1934 for "Device for Taking Cores or Samples From Wells," it was proposed that a drill bit be provided with a sort of a repeating gun which would drive hollow core takers into the earth formation ahead of the bit, the gun being operated from the surface of the ground. Because of its complicated firing mechanism, or for other reasons, this device has not come into general use.

In accordance with the present invention, it is proposed to improve upon the Bannister invention by an arrangement of drill bit and retrievable, explosive actuated core taker which is very rugged in construction and simple to operate.

The objects of the invention will be apparent to those skilled in the art from what has been said above, and from the following description of preferred apparatus when taken in connection with the accompanying drawings in which:

FIG. 1 is a vertical cross-sectional view of drill pipe or tubing and a bit, with an explosive actuated retrievable core taker being lowered therein;

FIG. 2 is a fragmentary cross-sectional view of drill pipe or tubing with a modified type of bit for use with a retrievable core taker like that illustrated in FIG. 1;

FIG. 3 is an enlarged and more detailed view, partly in cross-section, of the upper part of the retrievable core taker of FIG. 1; and

FIG. 4 is an enlarged and more detailed view, partly in cross section and partly cut away, of the lower part of the retrievable core taker of FIG. 1, FIGS. 3 and 4 being contiguous.

Referring to the drawing in detail, and first to the general assembly shown in FIG. 1, it will be seen that the pipe 15, which may be either drill pipe or tubing, is fitted with a drill bit 16 at its lower end.

The drill bit 16 has a central passageway 17 extending vertically therethrough. In accordance with known practice, the passageway serves to conduct drilling fluid through the bit in rotary drilling. The bit may have ordinary "fishtail" teeth, or it may be a roller or cone type bit, but must be provided with the passageway 17 so as to permit the movement of a core barrel therethrough, as will presently be described. At the top of the passageway 17, the bit 16 of FIG. 1 is provided with a conical seat 18.

In FIG. 2, a modified and preferred form of bit is illustrated. Here again the bit 20 is shown as being of the "fishtail" type, but it will be understood that it may be a roller bit or a cone bit or any other known type provided it has a central passageway 21 extending vertically therethrough.

In the bit 20 of FIG. 2, the passageway 21 is not only provided with a seat 22 at its upper end, but there is a second seat or shoulder 23 located a short distance below the seat 22. In addition to the passageway 21, there are two water courses 24 in the bit 20 of FIG. 2. These water courses are of conventional design and direct the drilling fluid into the proper relation with respect to the teeth of the bit. There is also a ball 25 or other object which prevents the flow of fluid through the passageway 21 when it is seated on the second seat 23 as illustrated. The ball 25 thus serves as a check valve preventing downward flow through the passageway 21. It may be so designed as to break when struck by the core barrel, as described hereinafter, or it may be provided with a fishing neck to be retrieved before a core is taken. Of course, it may also be removed from the bit by reverse circulation. When the ball is seated on the seat 23, fluid can flow downwardly through the bit through the water courses 24 and the bit thus operated in the conventional way.

The retrievable core taker of the present invention can be used with the simple type of bit shown in FIG. 1 or with the more specially designed bit of FIG. 2. In either case, it is lowered down through the pipe 15 on a wire line 30. This line is preferably a single strand of strong steel such as the Halliburton measuring line commonly used in the measuring of oil wells.

In accordance with known practice, there may be a stuffing box and "lubricator" at the surface of the ground, so that the core taker can be run into the pipe 15 while the well is under pressure.

The upper portion of the retrievable core taker consists of an explosive jar, and will not be described herein in detail. It may be constructed as shown and described in the co-pending application for U.S. patent of Myron M. Kinley, Serial No. 166,734 filed January 8, 1962 for an Explosive Jar.

When the explosive jar is manipulated by means of the wire line 30, a mechanical jar 31 causes the trigger section 32 to fire a powder charge in the section 33, and this drives a hammer downwardly to strike an anvil in the section 34.

It is within the purview of the invention to dispense with the hammer and anvil entirely and have the powder charge operate directly upon the core barrel, but the hammer and anvil arrangement are here illustrated because it may be desired to employ the additional impact which they afford.

As illustrated, there is a cylinder 35 attached to the lower end of the anvil section 34 of the retrievable core taker. The anvil projects into the upper part of the bore of the cylinder 35 and is located just above the core barrel 36, as shown in FIG. 4.

The core barrel 36 has an enlargement or head 37 at its upper end which serves as a sort of guide, being approximately the same diameter as the bore of the cylinder 35. The head 37 also serves as means to receive the downward thrust of the anvil when the explosive jar is fired, and it also limits downward movement of the core barrel

As shown in FIG. 4, the core barrel 36 is hollow for a major portion of its length, and its lower edge may be provided with an inner bevel, as illustrated.

The core barrel 36 is empty when being lowered into the pipe 15. Well fluid is prevented from entering it by the O-ring 38 located in the annular space between the outside of the barrel and the wall of the cylinder 35. A frangible disk 40 holds the core barrel in place until the explosive jar is fired, and until the disk 40 gives way, it is also maintains a seal excluding well fluid from the core barrel, being provided with an O-ring 39 at its outer periphery.

There is a guide head **41** screw-threaded on to the bottom of the cylinder 35. This clamps the disk 40 in position. It also serves to guide the barrel to its proper seat in the bit. For this purpose, it is tapered at its lower end, as shown at **42** to conform to the shape of the seat **18** in the bit shown in FIG. 1 or the seat **23** in the bit shown in FIG. 2, so that the core taker is properly located when lowered slightly more than is illustrated in FIG. 1 and FIG. 2.

The guide head **41** is provided with a vertical passageway **43** of slightly larger diameter than the outside diameter of the core barrel 36, and this passageway is tapered at its upper end, as shown at **44**, so that the core barrel is guided when it is driven downwardly through the passageway 43.

The guide head **41** has laterally extending holes 45 to permit escape of fluid when the core barrel enters the passageway 43. The holes 45 may also serve to accommodate a spanner wrench when screwing the head onto the cylinder 35.

To cushion the core barrel at the end of its travel, the annular space between the O-ring 38 and the disk 40 is filled with a heavy grease as shown at 46 in FIG. 4.

In operation, let it be assumed that the well has been drilled to the depth at which it is desired to take a core. The retrievable core taker, with the parts in the relative position shown in FIGS. 3 and 4, is then lowered down through the pipe 15 and placed in position on the seat **18** if the bit of FIG. 1 is used or the seat **23** if the bit of FIG. 2 is used. The seating of the core taker does not break the ball 25 of FIG. 2, assuming that it is still in position when the core taker is lowered into the pipe, but the ball 25 will break when the core barrel strikes it.

With the core taker in place, the wire line is manipulated to fire the powder charge. When this happens, the core barrel will be driven downwardly, as explained above, until the core barrel extends down through the passageway **43** in the guide head **41** and on down through the passageway in the drill bit. The core barrel will thus be driven down into the earth formation below the drill bit.

As the core barrel moves downwardly, its movement at the end of its travel is cushioned somewhat by the grease **46**, but eventually the enlargement 37 will come to rest in the tapered portion **44** of the passageway **43** if the core barrel has penetrated the earth formation sufficiently to permit full extension of the telescopic movement of the core barrel in the cylinder 35 and head **41**.

It will be observed that the core taker is not latched to the pipe 15 or the bit. The recoil or kick of the explosive jar does not place any stress upon the pipe 15 or the drill bit.

After the core is taken by the barrel, the entire core taker assembly may then be removed from the well by the wire line 30 without removing the pipe 15 and the

bit from the well bore. A sample of the earth formation immediately below the drill bit can thus be obtained, and the drilling can then be completed. If the bit of FIG. 2 is being employed, another ball 25, or the like should, of course, be dropped or pumped into position.

The invention is not to be regarded as limited to the particular arrangements shown and described herein. It is obvious that many changes may be made in the arrangement and construction of parts without departing from the spirit of the invention or the scope of the annexed claims.

I claim:

1. Apparatus for taking cores from the bottom of a well while it is being drilled including, in combination, a pipe with a drill bit thereon, said bit having water courses and, in addition, a vertical passageway centrally thereof, said passageway having a seat at its upper end and a second seat located therein beneath the first mentioned seat, an object which is adapted to break when struck resting on said second seat and serving as a check valve until broken, a core taker located in said pipe above said bit and having a guide head at its lower end adapted to rest on the upper seat of said passageway, said core taker including a jar, a powder charge, means for firing the powder charge when actuated by said jar, a core barrel, and means for driving the core barrel down through said passageway, thereby breaking said object, when said powder charge is fired, and a wire line connected to said core taker for lowering the same down through said pipe and for retrieving the same.

2. A core taker for use in oil wells or the like including, in combination, a wire line, an explosive jar secured to the line and having means for firing the same by manipulation of the line, a cylinder attached to and located below said explosive jar and having a core barrel mounted for vertical movement therein, a grease cushion located between said core barrel and said cylinder, means for driving the core barrel downwardly in said cylinder when the jar is fired, a head attached to the lower end of said cylinder having a vertical passageway therethrough in axial alignment with said core barrel whereby said core barrel may move downwardly therethrough when the jar is fired, said head also having means for seating in a drill bit and for positioning the core taker with respect to the bit so that the core barrel may move vertically downwardly out of said passageway and through the bit, and means for keeping said core barrel empty until the jar is fired.

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2,717,760	9/55	Bannister	175—4
2,729,292	1/56	Hinson	166—63

CHARLES E. O'CONNELL, *Primary Examiner.*

APPENDIX C

EVALUATION OF CONCEPTS

C.1 - Hughes Tool Company Concepts 1 through 19

C.2 - Foster-Miller Concepts A-1 through A-22 and FM-1 through FM-9

TOOL CONCEPTS 1-19

CONCEPT	GROUP	1	2	3	4	5	6	7	8	STATUS - APL EVALUATION	
MTC - 1 - 1A - 2 - 3 - 4 - 5 -16 -19 -B.1.3* -B.1.4* -B.1.5* -B.9.5* -B.9.6* -B.1.13*	1	1	1	2	1	2	1	1	1.22	REJECTED, REJECTED, REJECTED, REJECTED, REJECTED, RETAINED, REJECTED, REJECTED, RETAINED,	Probable seal damage thru overburden. Can't get rock sample if rock is fissured. Same reasons as 1 above. Can't get overburden or rock sample in permeable overburden of fissured rock. Same reasons as 2 above. Also incapacity to seat and seal against rock. Same reasons as #2 above. A feature which may be incorporated into an overall concept. Others are easier and more simple. Works as a rock sampler only. No capability in overburden sampling. Bulk of ideas expressed in these presentations were incorporated into the drawing shown on Page C.1.13. Group 1 evaluation was based primarily on this concept. This was held to be a contender if certain weaknesses could be eliminated. These were: (1) Try to use a valving system to permit batch loading and closed state transport, (2) Try to use a mechanical rather than pyrotechnic detach between casing and drill stem, (3) provide sample collector for overburden. APL to develop further.
MTC - 6	2	1	1	1	3	2.5	3	3	2.07	REJECTED,	Complex in application. Won't work in under-dense material.
MTC - 7	3	1	2	3	1	3	3	3	2.28	REJECTED,	Incapable of retrieving overburden samples of dust or rubble.
MTC - 8	4	2	3	2	2	1.5	2	2	2.07	RETAINED,	APL tests yielded good results. May be used as simple, separate overburden sampler. APL to develop further.
MTC - 9 - B.5.5* - B.5.6*	5	1	1	2	2	1.5	2	2	1.64	RETAINED,	Has possibilities, but finding a transport frequency compatible with drilling frequency is a problem. Two possibilities were suggested: (1) cycle such as drilling, pulling off bottom, and vibrating to transport; (2) super position of low frequency impact on a higher transport frequency. APL to develop further.
MTC - 10 - 10A	6	2	1	2	1	2	1	3	1.71	REJECTED, REJECTED,	Can't "sense" hardpan under overburden. Problem with developing grouting systems for severe environment. Basic objection was grout material problem. Didn't provide for required drilling system.
MTC - 11 - 12 - 12A - 13 - 14 - 15 - B.8.10* - B.8.11* - B.8.12*	7	1.5	1	1	1	2	1	2	1.36	REJECTED, RETAINED, REJECTED, REJECTED, REJECTED, REJECTED, REJECTED,	Nature of lunar dust charge is not known. Could acquire and transport dust or rock sample. Per APL, rock sample not as good as Rotary-Impact for . . Problems with sealing on uneven rock surfaces. Inability to cut and acquire hard rock. Won't work on cohesive overburden. May be applicable as an overburden sampler only, but would have no application for rock sampling. Consolidation of ideas in this group were developed in B.8.10, B.8.11, B.8.12. Group 7 Evaluation largely based on these presentations. System generally held to be not competitive on basis of weight, complexity, and capability. No further development due to limited chances of success.
MTC - 17 - 18 - 18A	8	2	2	2.5	1	2	1	2	1.78	REJECTED, REJECTED, REJECTED,	Air blast and ejecta would imperil other systems. Too complex. Can do same job with one penetrator, repeated impacts, and controlled gas flow system. Difficult to recover core barrel in hard rock, to hold core in barrel, and to recover core from barrel.

Legend for Task And Characteristic Numbers:

1. Gain Access to Rock Under Overburden without Contamination
2. Fragment Rock to Produce Sample
3. Acquire Rock Particles for Sample without Contamination
4. Transport Rock Particles for Sample
5. Acquire Overburden for Sample
6. Transport Overburden for Sample
7. Complexity of System
8. Composite Rating

Legend For Rating Numbers:

1. = Good
2. - Questionable
3. - Poor or Impossible

Note: On complexity Rating, 1 - Easy to Achieve
3 - Difficult to Achieve

* Refers To Pages in Appendix.

FOSTER-MILLER CONCEPTS A1 THROUGH A-22 AND FM-1 THROUGH FM-9

CONCEPT	APPENDIX PAGE NO.	HTC EVALUATION TASK OR CHARACTERISTIC NO. 1	2	3	4	5	6	7	8	FM EVALUATION	HTC - JPL EVALUATION
FM - A1	A.1.15	1.5	1.5	1	3	2	3	2	2	RETAINED	REJECTED. Scale looks improbable. Problems are contamination are inefficient vertical trajectory.
- A2	A.1.16	1.5	1.3	2	3	1	1.5	2.5	1.8	RETAINED	RETAINED. Overburden and rock in one trip looks good. Simple. FM to develop further.
- A3	A.1.17	1	1	2	2.5	2	2	3	1.9	REJECTED	REJECTED. Mechanical complexity.
- A4	A.1.18	2	1	2.5	3	2.5	3	2	2.3	REJECTED	REJECTED. Mechanical complexity. Transport capability questionable.
- A5	A.1.19	1	1	2	2	2	2	3	1.9	REJECTED	REJECTED. Contamination. Seal difficulties. Operating in dust a problem.
- A6	A.1.20	2	1	2	3	2	2	2.5	2.1	REJECTED	REJECTED. Contamination. Separate trips required for rock and overburden. Connection problem.
- A7	A.1.21	2	3	1	2	1	2	2.5	1.9	REJECTED	REJECTED. Can't cut basalt with buckets. Also friction, sticking, clearance problems.
- A8	A.1.21	2.5	1	2.5	2.5	2.5	2.5	1	1.6	REJECTED	REJECTED. Not feasible due to low taper angle, plus particle irregularities and collisions.
- A9	A.1.22	1	1	2	2	2	2	2.5	1.8	REJECTED	REJECTED. Promising, but requires considerable development. JPL to study further.
- A10	A.1.23	2.5	1	2	3	2	3	1.7	2.2	REJECTED	REJECTED. Contamination. Geometry difficult. Valve increase impedance to inner chamber.
- A11	A.1.24	1	1	3	2	3	2	2	2.0	RETAINED	REJECTED. Won't work in non-cohesive dust, permeable dust, or fissured rock.
- A12	A.1.25	2	1	2.8	2	3	2	2.5	2.2	REJECTED	REJECTED. Gas flow impedance uncontrollable. Won't work in non-cohesive dust or fissured rock.
- A13	A.1.26	2	1.3	2	1	3	1	2	1.8	RETAINED	REJECTED. A valving form. Consider as valving prospect for closed gas transport system.
- A14	A.1.27	1	1	2.5	3	2	3	2	2.1	RETAINED	REJECTED. Sample contamination.
- A15	A.1.28	1	1	2	1.2	2	1	1	1.3	RETAINED	RETAINED. Essentially same as HTC Group 1 (B.1.13), with similar weaknesses.
- A16	A.1.29	1	1	3	2	3	2	1.2	1.9	RETAINED	REJECTED. Gas flow paths not predictable. Same category as FM-A11.
- A17	A.1.30	1	1	2	2.5	2.5	2.5	2.5	2.0	REJECTED	REJECTED. Problems with sample mixing and recovery.
- A18	A.1.31	1.5	1	1.5	1	2	2	2.7	1.7	RETAINED	REJECTED. A possible valving form with gas transport. Problems are particle size control and complexity.
- A19	A.1.32	1	1	2	1.2	3	2	1	1.6	RETAINED	REJECTED. Not suitable in dust or fissured rock. A possible valve form for gas transport.
- A20	A.1.33	1.5	1.3	2	[illegible]	2	1.5	3	1.8	REJECTED	RETAINED. As a valving form for closed gas transport.
- A21	A.1.34	2	1.2	2	2.5	2	2	3	2.1	REJECTED	REJECTED. Not applicable to rock sampling.
- A22	A.1.35	1.5	3	1.5	1.8	2	2	2.7	2.1	RETAINED	REJECTED. Contamination.

CONCEPT*	APPENDIX PAGE NO.	EVOLVED FROM CONCEPT	REMARKS
FM - 1	A.2.3	FM - A1	REJECTED. Improbability of efficient vertical transport remains.
- 2	A.2.4	- A15	RETAINED. Still with original weaknesses (similar to HTC Group 1). Greatest need is closed system gas transport.
- 3	A.2.5	- A19	REJECTED. Basic objection is that it won't work in dust or fissured rock. Needs closed system gas transport.
- 4	A.2.6	-A11- A16	REJECTED. Better structure, but basic objection regarding operation in dust or fissured rock has not been eliminated.
- 5	A.2.7	- A13	REJECTED. Improved version with overburden capability. However, removal of overburden from carrier is problem. Inner chamber is a valve form.
- 6	A.2.8	- A22	REJECTED. Contamination still a problem. Also doubtful ability of the lower chamber to enclose and retain the rock sample.
- 7	A.2.9	- A2	RETAINED. An improved version of A2. However, problems with respect to recovery of overburden and rock samples at surface remain.
- 8	A.2.10	- A18	REJECTED. Particle size control is probably better than A18, but recovery of both samples at surface is still a problem.
- 9	A.2.11	- A14	REJECTED. Objection on basis of contamination removed by seal. Recovery of rock sample at surface a problem.

* These more fully developed concepts were not evaluated in the same manner as the original group of 22. Remarks above are intended to indicate whether the developments substantially changed the original evaluations.

Legend for Task and Characteristic Numbers:

1 - Gain Access To Rock Under Overburden Without Contamination
2 - Fragment Rock To Produce Sample
3 - Acquire Rock Particles For Sample Without Contamination
4 - Transport Rock Particles For Sample
5 - Acquire Overburden For Sample
6 - Transport Overburden For Sample
7 - Complexity of System
8 - Composite Rating

Legend for Rating Numbers:

1 - Good
2 - Questionable
3 - Poor or Impossible

Note: On Complexity Rating, 1 - Easy to Achieve
3 - Difficult To Achieve